PRODUCT ENGINEERING

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Social Problems and the Engineer

WE ARE taking the liberty of excerpting the following from the commencement address delivered by Gano Dunn, president of Cooper Union and president of J. G. White Engineering Corporation, to the graduating class of the Massachusetts Institute of Technology. An educator, engineer and industrialist, Mr. Dunn has packed into a few well-chosen words much food for thought.

"The engineer today finds himself in a pivotal position in industry, intermediate between capital and labor, with the problems of both of which he deals intimately and is in a position to understand, interpret and judge.

"There is in consequence offered to him, entirely in addition to the service which he performs through his engineering functions, an opportunity for social service through his professional and personal status which, if he rightly conceives and seizes it, gives him a strategic advantage to render social service, which at this moment the representatives of the older professions do not possess.

"Is it too much to hope that with an enlightened method of approach and the habit of factual investigation, which are the intellectual birthrights of the engineer, his increasing participation in management may bring to the solution of some of the social problems of industry a prejudice dissolving light?

"In the precipitations of relationships brought about by big business and mass production, the function of management has fallen very largely to the engineer. In the field of management, involving the play of the human spirit at its best and at its worst, where, particularly in labor relations, generosity, loyalty, and independence are manifest as well as passion, ignorance and vanity, the engineer's capacity for organization, leadership, and sympathy has rare opportunities.

"Even in these days, which we often think to be so far advanced, the sway of prejudice and of certain kinds of superstition is still profound. It awaits the light of reason and human understanding.

"Executions for witchcraft were once a common part of everyday life. At the time when Salem shocked the colonies by nineteen such executions, literally thousands of witchcraft executions every year were carried out in Europe. Over a period of forty years there were eight thousand such executions in intelligent Scotland alone.

"But the social sphere today is still a field which needs the light, a field in which the engineer with his training and his point of view has open to him doors of rare opportunity. While not as sinister as the witchcraft problems, there are problems of prejudices in our social field that are, like the witchcraft, based on distrust and ignorance, problems that act as a brake on industry and separate man from man, problems that challenge every engineer.

"While I have dwelt upon the essentially economic character of the engineer's field and the social service rendered by him in the cultivation of that field, such social service is an indirect one, effected by his function rather than by a disinterested will to serve. It is not what the engineer does, but how he does it; not what the engineer's occupation is, but the intellectual processes by which he attacks that occupation, that sets the engineering profession apart from the other professions."

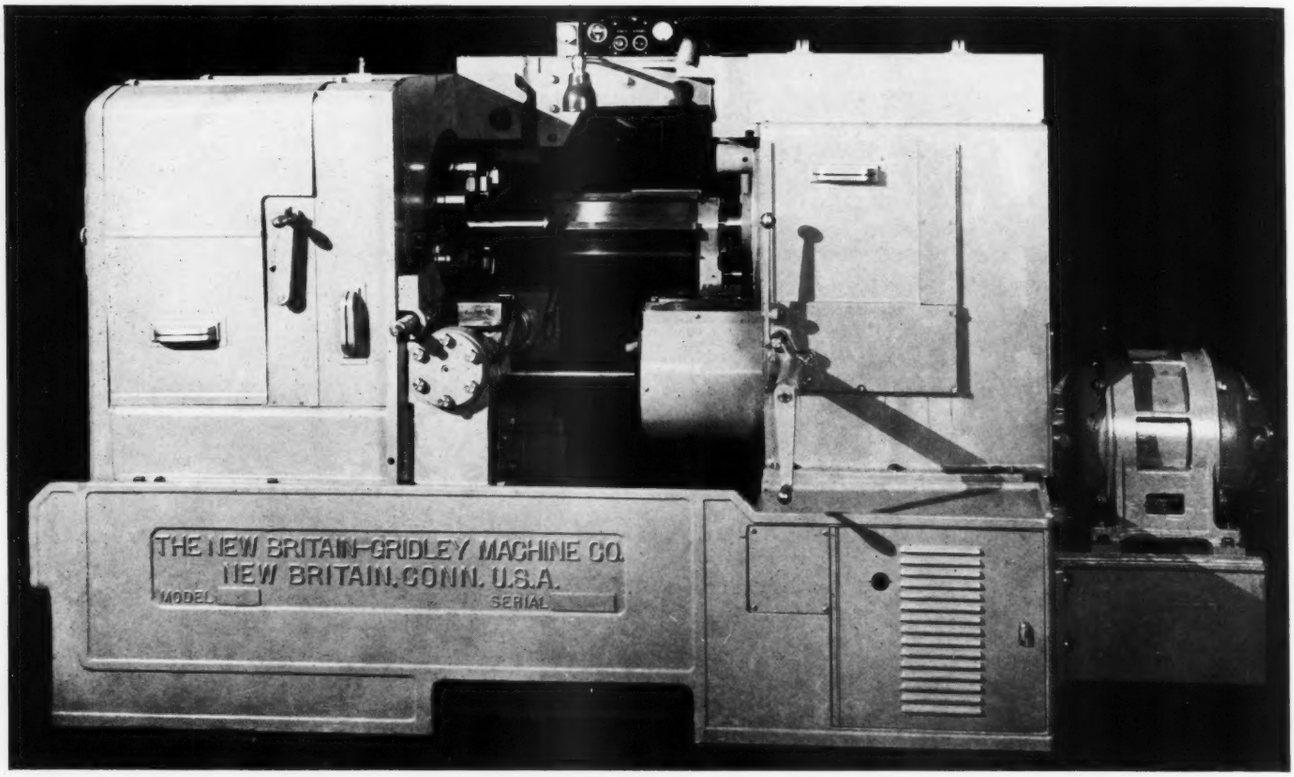


Fig. 1—Six-spindle work-rotating chucking machine—The New Britain Machine Company's latest model, in which unique mechanical, electrical and hydraulic interlocks have been developed for safe automatic operation

HYDRO-ELECTRIC CONTROLS

In Automatic Screw Machine

Interlocks assure that spindle motors will be inoperative unless hydraulic system is at working pressure and provide automatic control of feed clutch. To eliminate wear on locating surfaces, spindle carrier is lifted automatically during indexing

THE LINE of chucking machines recently introduced by The New Britain Machine Company, contains a number of exclusive design features of unusual interest. Latest in this line of machines is a six-spindle work-rotating chucking machine, especially developed for high-speed chucking jobs where six tooling positions can be used to advantage, wherein all of the exclusive features found in the preceding models of this recently introduced line of screw machines and chucking machines are incorporated and further developed.

Among the features is a patented hydraulic system which provides instantly adjustable chucking pressures within a range of from 40 to 300 lb. per sq. in., the chucking being operated in conjunction with synchro-mesh positive jaw clutches on the spindles mounted in the carrier. Automatic devices, as will be explained, prevent feeding if the hydraulic chucking pressure is below that required for gripping the work; will prevent operation of the machine until the necessary pressure has been built up for gripping the work, and will prevent indexing until the chuck is closed and the spindle clutches are engaged. A mechanical interlock makes it impossible to engage the power feed when the hand feed is being used or is in gear.

Details of the hydraulic circuit are shown in the accompanying diagram, Fig. 2—the relative pressures in the various parts of the circuit being indicated by the different colors.

A pressure-operated switch actuated by the pressure in the hydraulic circuit is located in the electric control box on top of the machine. This switch closes the pilot control circuit of the main motor when the hydraulic system has reached the predetermined necessary pressure for the proper operation of the machine. Thus the 20 hp., 1,200 r.p.m. main drive motor cannot be started until the hydraulic pump has built up the required pressure both for operating the hydraulic units and for furnishing lubricating oil to all bearings, the one hydraulic pump being used for both purposes. And if at any time the pressure in the system falls below the required amount, the pressure switch will open and shut down the machine. The hydraulic pressure for correct operation must of necessity be different for each

particular job, as determined by the nature of the piece to be chucked, and the pressure switch is set to close at the pressure desired. This pressure may be varied between 40 and 300 lb. per sq. in., as required.

When the machine is to be put in operation, the hydraulic pump motor must be started first. The oil is drawn from the reservoir through a filter by the constant speed hydraulic pump which forces the oil under pressure to the spindle cylinders, to the accumulator, to the pressure switch, and through leads to lubricate the various working parts of the machine. When the required pressure has been established, the main drive motor is started.

The main object of the accumulator is to store up a supply of oil under pressure, this oil to be used for obtaining quick action in opening and closing the chucks and in starting and stopping the rotation of the spindle in the loading position. Pressure in the accumulator forces the oil from a pressure controlled valve through the chuck and clutch operating valve to the spindle cylinder, as shown in the accompanying diagram of the hydraulic circuit. Operation in the loading position is controlled through the chuck and clutch operating valve by means of a hand chucking lever.

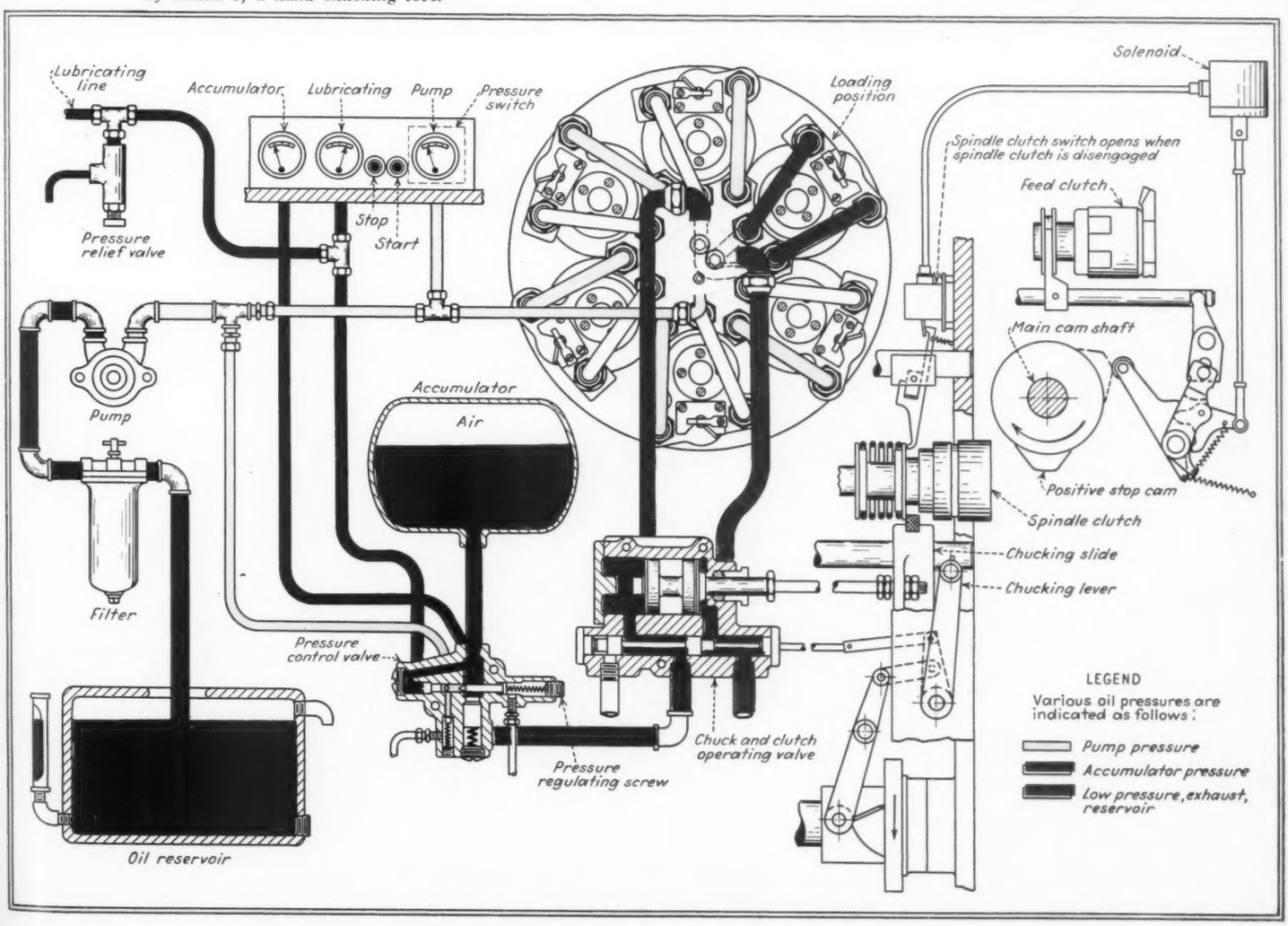
Automatic Clutch Control

Rotation of the spindle is stopped automatically in the loading position at the proper point of every cycle. This is accomplished by the clutch operating slide connected to the piston in the operating valve. When the spindle clutch is disengaged, a spring energized switch opens the solenoid circuit which controls the operation of the power feed clutch mechanism, as shown in Fig. 3. Should the operator fail to complete the chucking operation during the machining time, the positive stop cam on the main camshaft actuates the levers which throw the feed clutch out of engagement and the machine stops. Thus the hydraulic and mechanical functions of this machine are combined with the electric controls to obtain the maximum efficiency in operation, to provide protection for the operator and to prevent the machine from operating without proper lubrication or incorrect hydraulic pressure, or operating in any but the correct sequence.

An oil pressure release valve is placed in the lubricating line to maintain a constant oil pressure on the parts to be lubricated. Oil drains off from the lubricated parts back into the one reservoir and is used over again, the same hydraulic pump furnishing the oil for both the hydraulic system and the lubricating system.

In Fig. 3 is also shown the safety device whereby the power feed and hand feed are interlocked so as to prevent the power feed from being engaged when the hand feed is being used or is in gear. When the hand feed crank is engaged, a spring plunger locks the power feed clutch shaft, preventing the power feed

Fig. 2—Oil from accumulator passes through pressure control valve to chuck and clutch operating valve, to spindle cylinder. Operation in the loading position is controlled through the chuck and clutch operating valves by means of a hand chucking lever



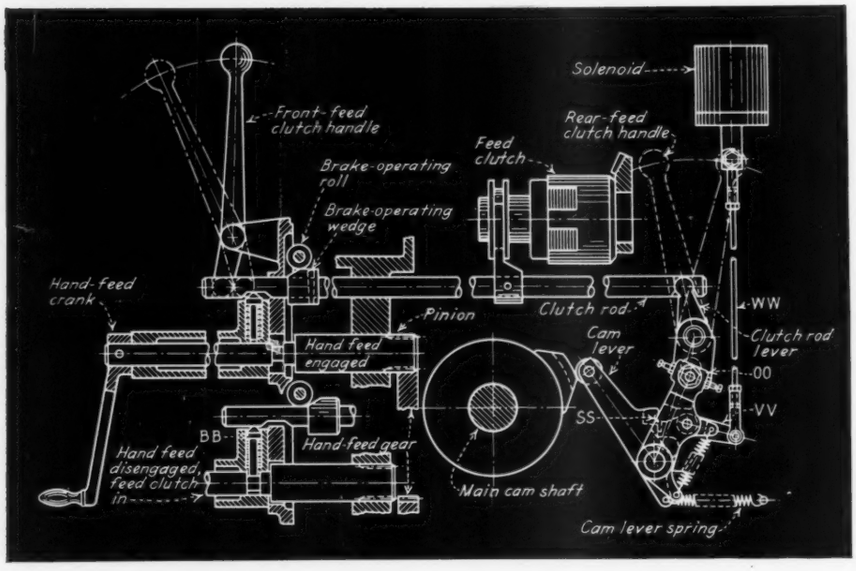


FIG. 3—SAFETY FEED MECHANISM. With the machine in normal operation, the feed clutch handle will be forward. The solenoid circuit will be closed, which holds up the rod "WW" and keeps levers "VV" and the cam lever out of contact at "SS". The came on main cam shaft merely rocks lever "UU" back and forth. When the solenoid circuit is opened, either intentionally or automatically by failure to complete the chucking operation during the machining time, rod "WW" will no longer be held up and the spring will pull lever "VV" to make contact with lever "UU" at "SS". When the cam now lifts the roller, the cam lever and "OO" will rotate on their common center, and throw the clutch rod lever counter-clockwise, thereby disengaging the feed clutch.

The machine cannot be thrown into high speed or feed while the hand feed crank is engaged, in which position plunger "BB" prevents motion of the feed clutch shaft. Before the feed clutch handle can be pulled forward to engage the feed clutch, it is necessary to pull the hand feed crank forward out of engagement with the hand feed gear. This allows plunger "BB" to be depressed, its lower end moving into the groove on the hand feed crankshaft when the feed clutch handle is pulled forward.

▼

clutch from being thrown into engagement. Before the feed clutch handle can be pulled forward to engage the feed clutch, it is necessary to pull the hand feed crank forward thereby disengaging the hand feed gear. This allows the spring plunger to drop into the groove on the hand feed crankshaft, thereby permitting the feed clutch handle to be pulled forward to engage the disk type power feed clutch.

Another highly interesting mechanism is the device for lifting the spindle carrier during the period of indexing. The purpose of this is to practically eliminate all wear on the spindle carrier locating pads. The details of the mechanism and its method of operation are evident in Fig. 4. During the indexing phase of the cycle, the lifting cam raises the carrier about 0.15 in., holding it in contact with the two rollers mounted on the frame of the machine to locate the spindle carrier during its rotation, the weight of the carrier being borne by the bronze lifting shoe. The modified Geneva mechanism, designed to operate at extremely high speeds without shock, then indexes the carrier, giving it an over travel of approximately 0.045 in. As can be seen from Fig. 4, the locking lever cam then releases the locking lever permitting it to be pulled by the spring so that the sloping faces of the locking lever and the locating block come in

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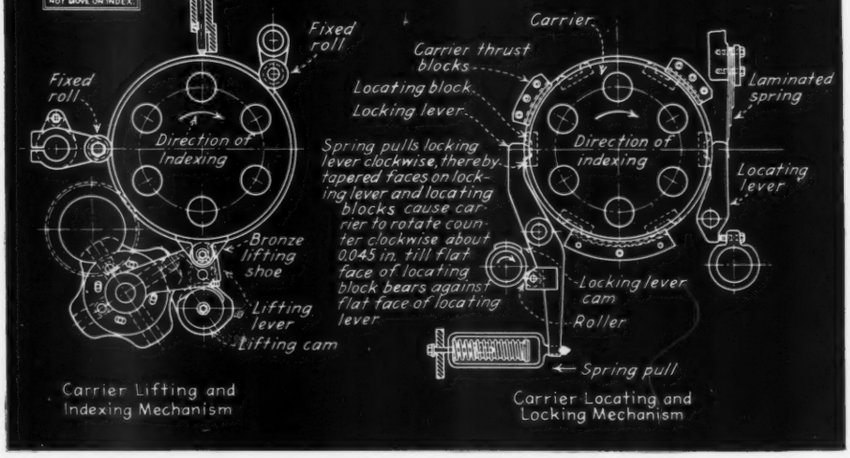
FIG. 4—CARRIER LIFTING MECHANISM. Indexing of the spindle carrier is by a modified Geneva motion. The entire mechanism is located at the rear of the spindle carrier, entirely inclosed. To eliminate wear between the spindle carrier and its locating pads on the frame the carrier is lifted about 0.015 in. during the indexing phase of the cycle by the action of the lifting cam on the roller attached to the lifting lever which is fulcrumed on the indexing shaft and carriers the bronze lifting shoe. During indexing the carrier rotates on the bronze bearing shoe in conjunction with the two fied rolls, all three bearing against a special wearing surface on the carrier. Thus, the surfaces that locate and support the carrier during the working phase of the cycle are kept out of contact while motion takes place between them. The functioning of this lifting mechanism is indicated by the lift indicator on top of the spindle carrier housing.

LOCATING AND LOCKING MECHANISM. As soon as indexing has taken place, the locking lever, which during the indexing is held clear of the carrier by the action of the locking lever cam, is brought into contact with the locating block by the pull of the spring. An overtravel of 0.045 in. has been incorporated in the design of the indexing mechanism. The contacting faces of the locking lever and locating block being on a slope, the carrier is turned counter-clockwise by the pull of the locking lever spring, until the flat surface on the opposite locating block is brought against the face of the locating lever. During indexing, the locating lever is forced out of the locking block and rides on the surface of carrier until it is again pressed into the next block by the action of the laminated spring.


STOP MACHINE IF INDICATOR DOES NOT MOVE ON INDEX.
Lift indicator
Fixed roll
Fixed roll
Direction of Indexing
Bronze lifting shoe
Lifting lever
Lifting cam
Carrier Lifting and Indexing Mechanism
Carrier
Carrier thrust blocks
Locating block
Locking lever
Laminated spring
Spring pulls locking lever clockwise, thereby tapered faces on locking lever and locating blocks cause carrier to rotate counter clockwise about 0.045 in. till flat face of locating block bears against flat face of locating lever
Direction of indexing
Locating lever
Locking lever cam
Roller
Spring pull
Carrier Locating and Locking Mechanism

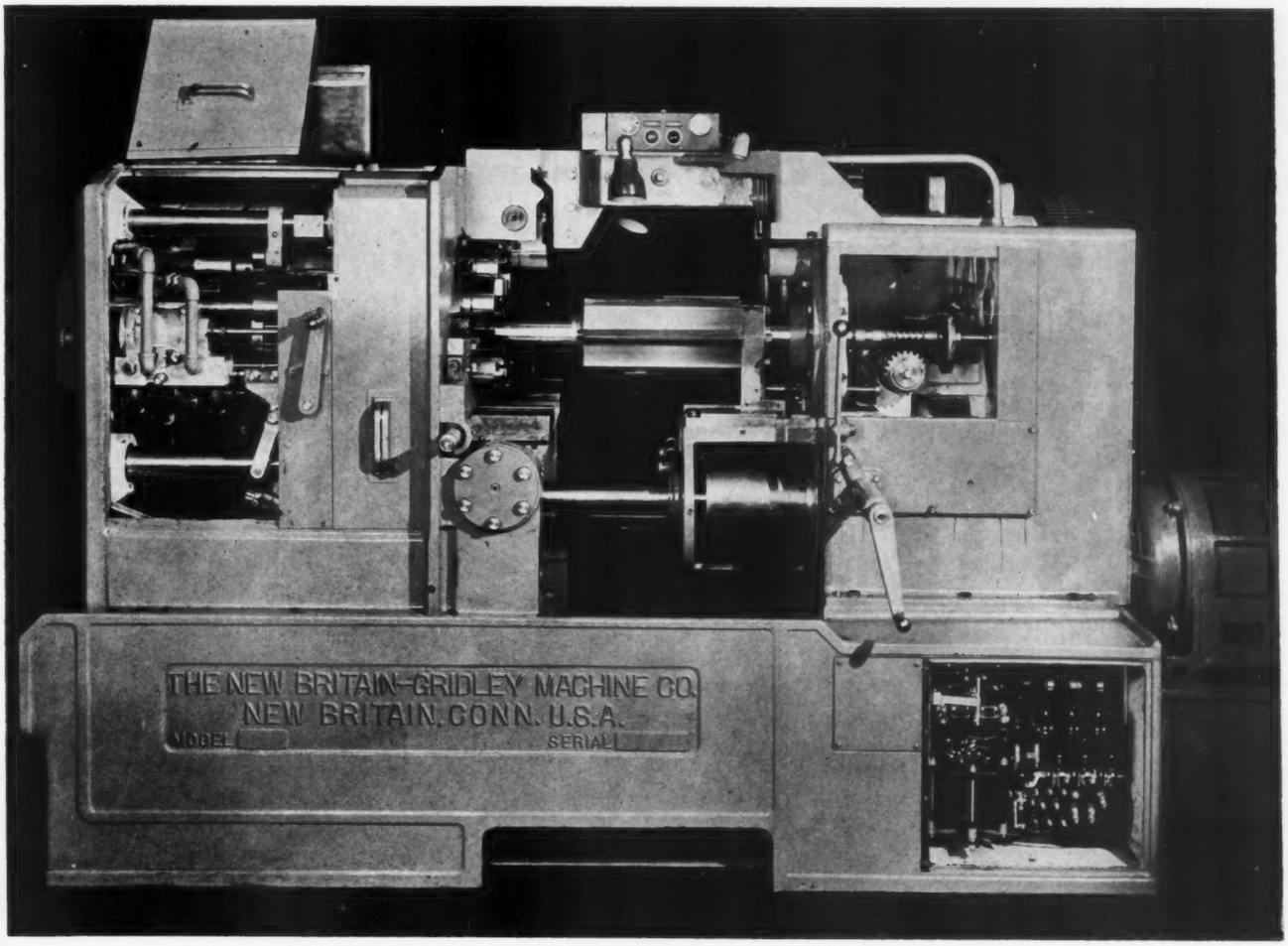


Fig. 5 – Rear view of the machine with the covers removed. Thus all parts of the machine that must be adjusted for different jobs are readily accessible

contact and rotate the carrier in a direction opposite to the direction of indexing until the flat surface of the opposite locating block is brought against the face at the end of the locating lever. At the same time, the bronze lifting shoe drops down and the carrier is positioned by its locating pads.

The spindle carrier is of extra large diameter with the tool slide stem forming practically an integral unit therewith. The carrier is finished to extremely close limits for preloaded ball bearing spindle mountings. The locking bolt slots are hardened and ground. In order to eliminate the possibility of deflection, the spindles are short in length and of extra large diameter.

General Construction Features

The machine can be equipped with six 5¾-in. two or three-jaw chucks, or special fixtures to suit special jobs. Rotating tools can be used in all positions and threading or tapping attachments can be used in any or all of the last three positions.

Other construction features include headstock and power box rigidly bolted and doweled to the base, both tied together with a heavy duty connecting member. The power box is entirely inclosed, automatically lubricated, with all revolving shafts mounted in anti-friction bearings. All shafts are of alloyed steel and all the gears heat-treated and finished after heat-treatment. The feed clutches and the high and low-speed clutch are of the multiple disk type and the high and low-speed clutches are accessible for adjustment through large aliding oil-tight panels.

The three cross slides are mounted on extra large diameter, hardened and ground circular studs entirely inclosing the bearings and thereby eliminating all possibilities of chips or grit working into the bearing surfaces. The slides are fitted with hardened and ground tool holder bases, the key slots of which are ground to size and in parallelism with the axes of the spindle. The cross slide cams are of the flat disk type, jig drilled and hardened, entirely inclosed and automatically lubricated. They are quickly removable and may be transposed to any one of the three cross slide positions.

In appearance the machine follows the same box-type construction that characterizes the previous Model 61 six-spindle automatic screw machine of this line. Ample chip space and maximum tooling accessibility is provided to assure ease of set-up and minimum maintenance time. This facilitated by sheet steel covers that can be swung or slid out of the way.

Great deal of attention has been paid to details of finish. Pressure gages mounted on top of the machine on the same panel with the start and stop buttons, as can be seen in the illustrations, indicate at all times the pressure in the accumulator, in the lubricating system, and the delivery pressure of the hydraulic pump. On each side of the machine is a built-in lamp, the two lamps providing "shadowless" illumination of the tools and work.

As can be seen in Fig. 5, the automatic controls are housed in the base of the machine and are readily accessible by sliding the lowered cover out of the way. The driving motor is mounted at the end of the machine with a silent chain drive to the main spindle.

Product Developments

Force-Feed Lubrication System Featured in Design of Compressor

A completely internal force-feed lubricating system, with all unsightly external piping eliminated, is one of the numerous improvements in the latest designs of vertical twin cylinder, single-acting inclosed Freon compressors built by the Vilter Manufacturing Company. Another feature is the design of the rotary oil seal stuffing box at the flywheel end of the crankshaft.

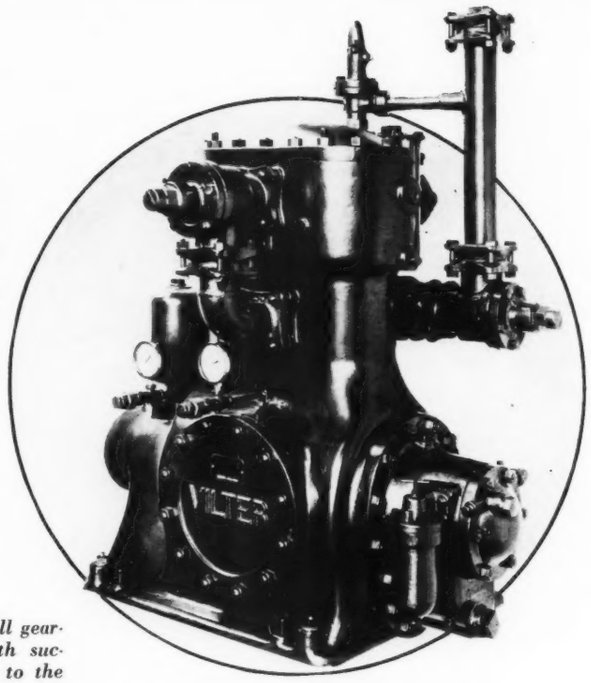


Fig. 1 — Vertical twin cylinder, single-acting inclosed Freon compressor — Vilter Manufacturing Company's latest model with completely internal lubricating system and triple oil seal

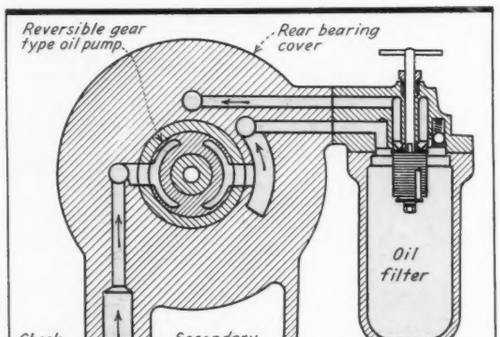
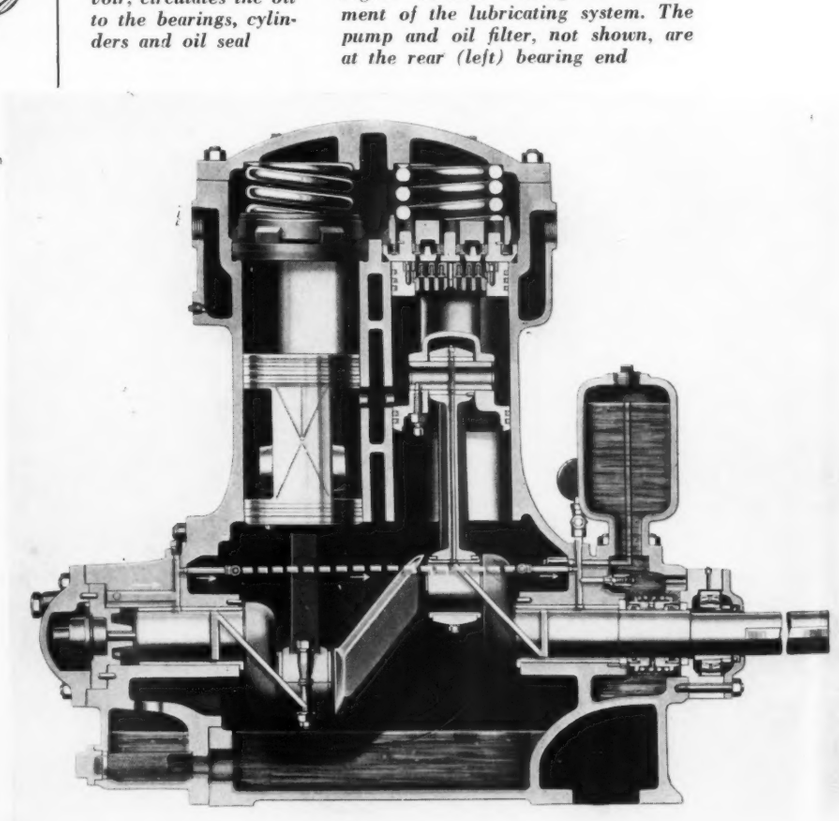


Fig. 2—A Tuthill gear-type pump with suction connected to the secondary oil reservoir, circulates the oil to the bearings, cylinders and oil seal

Fig. 3—Section showing the arrangement of the lubricating system. The pump and oil filter, not shown, are at the rear (left) bearing end



Details of the design of the compressor are shown in Figs. 2, 3 and 4. Referring to Figs. 2 and 3, the crankcase of the compressor forms the main oil reservoir. The lower half of the main bearing cover is designed as a secondary oil reservoir, a large opening near the bottom connecting it to the main reservoir. The removable screen prevents floating or suspended foreign particles from entering the secondary oil reservoir.

As shown in Fig. 2, the suction side of the Tuthill reversible gear-type oil pump is connected to the secondary oil reservoir and pumps the oil through a Cuno oil filter and from there to the distributing header and main bearings. Drilled holes in the crankshaft conduct the oil from the main journals to the crankpins, then to the piston pin through a rifle-drilled connecting rod.

One of the major problems in this design was to devise a stuffing box that,

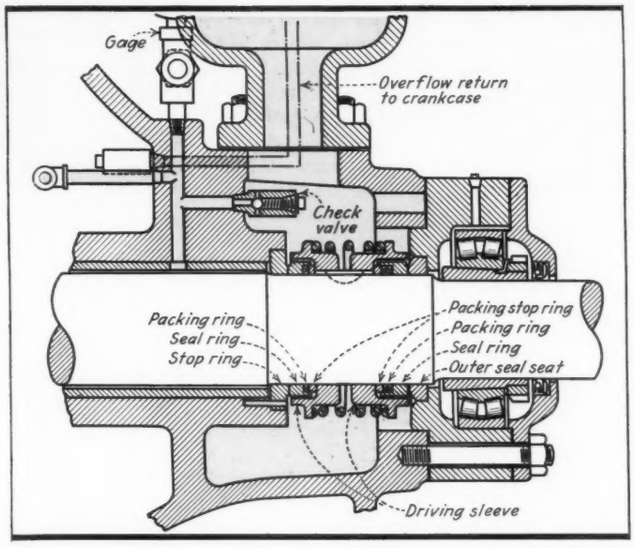


Fig. 4—Details of the design of the rotary oil seal at the flywheel end of the crankshaft

even during and after long periods of shut down would provide an effective seal to prevent air from entering into the crank case when running with a partial vacuum on the suction side of the compressor and would prevent the refrigeration medium, Freon, from leaking out when the crankcase pressure was above atmospheric. Provisions had to be made so that the seal would always be lubricated.

In Fig. 4 is shown the details of the stuffing box seal as finally developed. To assure a generous supply of lubricant to the seal at all times, a closed reservoir similar to the air dome or cushion chamber used on reciprocating pumps, is placed as shown in Fig. 3 and partly in Fig. 4. Oil is pumped into the reservoir through the check valve which prevents the oil from flowing back into the crankcase when the latter is under a partial vacuum. The spring loaded check valve also assures sufficient lubricant being furnished to all wearing surface before oil is allowed to flow into the dome. And because the oil dome is directly connected to the stuffing box chamber, the seal in the stuffing box will always have a plentiful supply of oil even when the compressor is not running.

After the level of the oil in the dome has reached the top of the overflow pipe, the oil drains out through the overflow pipe and through a metering device and thus back to the crankcase.

Referring to Fig. 4, the rotary oil seal stuffing box consists of two driving sleeves keyed to the crankshaft by a Woodruff key. A helical compression spring bears against flanges on the driving rings. As labelled in Fig. 4, the other elements are the packing stop ring, neoprene packing rings to seal the rotating alloy steel inner and outer seal rings to the shaft, and the bronze seal ring seats which have been lapped with their respective alloy steel seal rings. The portion of the crankshaft located in the seal compartment is chromium plated to provide a mirror smooth non-corrosive surface.

Although two main bearings could readily support the entire crankshaft, in order to assure great rigidity in the shaft seal compartment an auxiliary grease packed roller bearing has been provided at the flywheel end.

Other design features include crankcase and water jacketed cylinders cast in one piece, main bearings and crank pin bearings of bronze backed babbitt and the pistons of close grained cast iron with three compression rings at the top and two rings at the bottom. V-belt drive is standard.

Electronic Skew Corrector

On the Winsor & Jerauld Company's cloth-straightening machine is an ingenious photoelectric control system arranged to detect any skew which may occur in the "weft" or crosswise threads of the cloth during the tentering process and to transmit impulses that correct the deviation.

The control system, developed by the General Electric Company's general engineering laboratory, utilizes two scanning mechanisms. In each, as shown in Fig. 1, a light source with a suitable optical system projects a moving light spot, *C* or *D*, producing light beams *A* and *B* respectively. Motion of the light spot is effected by two rotating disks having slits

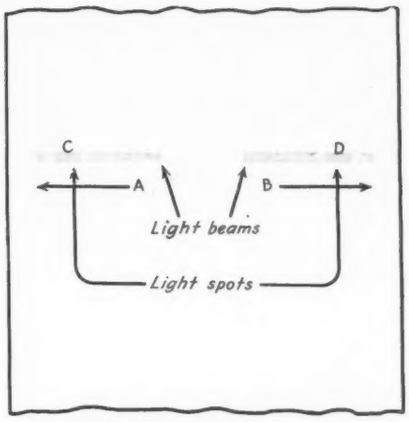


Fig. 1—Motion of light spots producing light beams

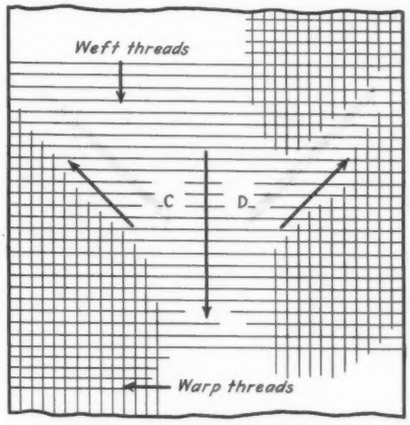
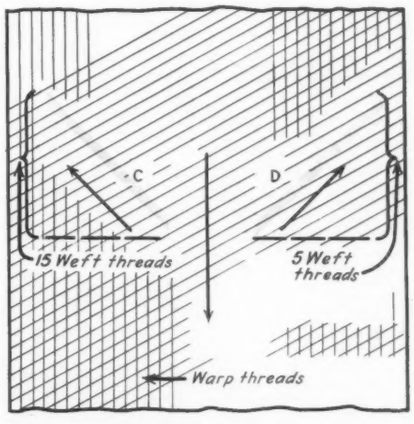


Fig. 2—Motion of light beams relative to cloth



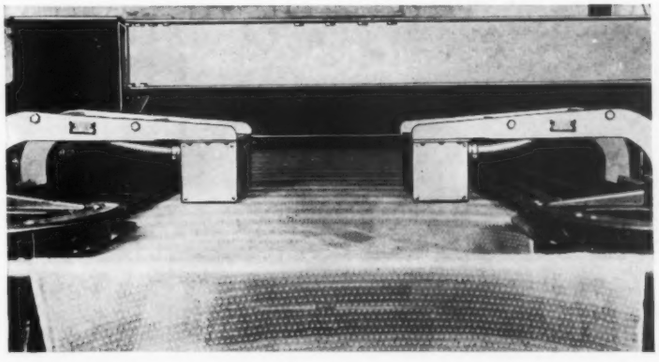


Fig. 3—Skew causes beams to intercept unequal number of weft threads

Fig. 4—Method of mounting phototubes on each rail of tenter

through which the light passes. The disks are driven by self-synchronizing motors tied in with the main drive of the tenter so that the motion of the light spots will bear a direct and constant relation to the speed of the cloth throughout the speed range of the equipment.

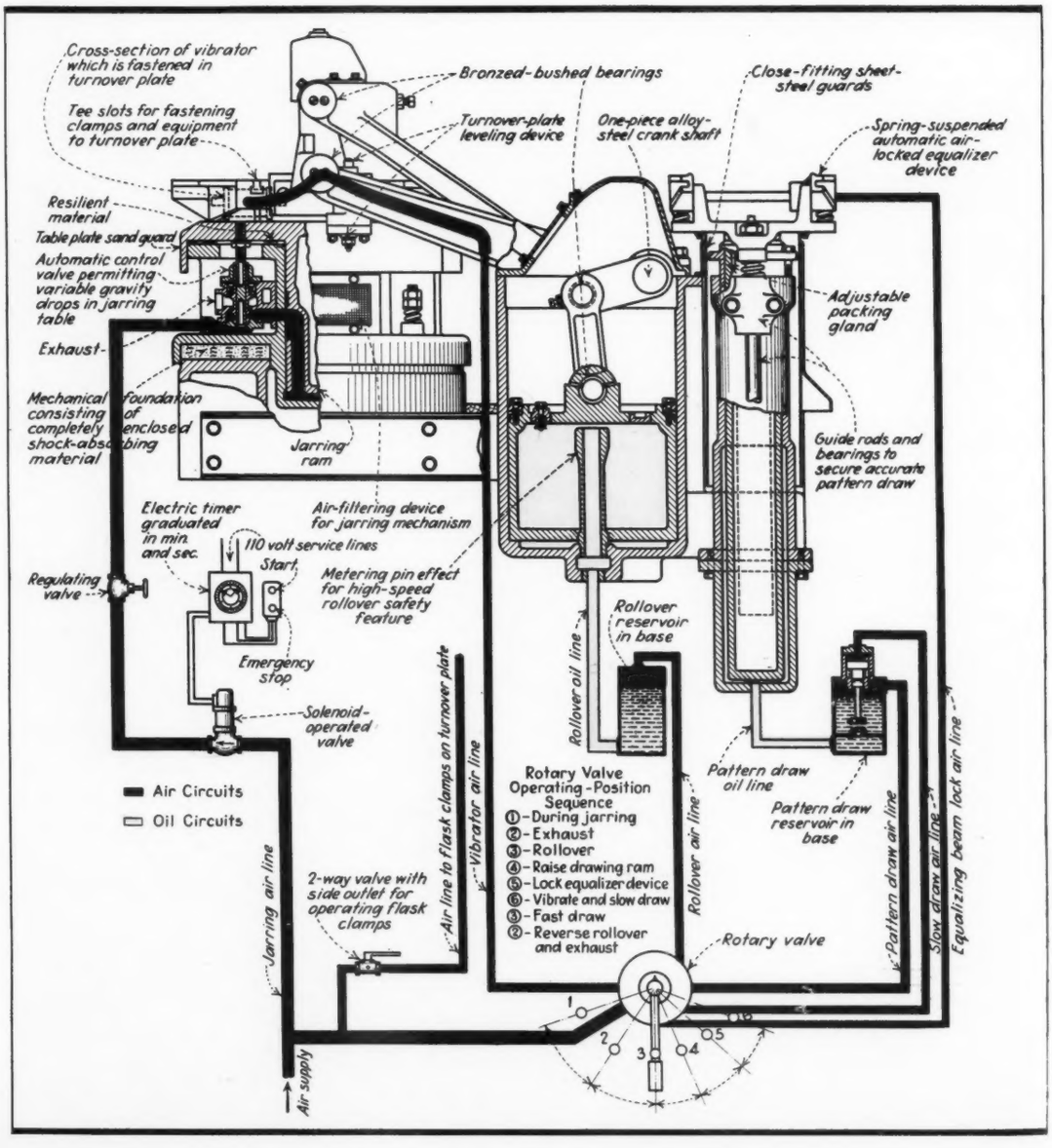
From each of the two optical systems, one on either side of the machine, the light passes upward through the cloth and is directed on one of two phototubes, each mounted directly above an optical system. As the cloth advances, the weft threads interrupt the light beams. To obtain definite interruptions, each beam must be completely intercepted by a single thread and yet be long enough to scan a representative section of the cloth. The dimensions of the beams used are $2\frac{1}{8} \times 0.005$ in. measured at the cloth where the focal line is located. The interruptions therefore cause definite light-frequency inputs to the tubes.

If the cloth is straight, as indicated in Fig. 2, the frequencies on the two tubes will be equal. If the cloth is skewed, as indicated in Fig. 3, the light frequencies will be unequal, since the path of spot *C* will intercept more threads than the path of spot *D*. Suitable amplifiers connected to the phototubes operate a frequency-responsive circuit in which the difference in frequencies is used to operate two relays. The relays control the operation of a straightening motor which acts through a differential gear to advance or retard the tenter chains, thus correcting the deviation.

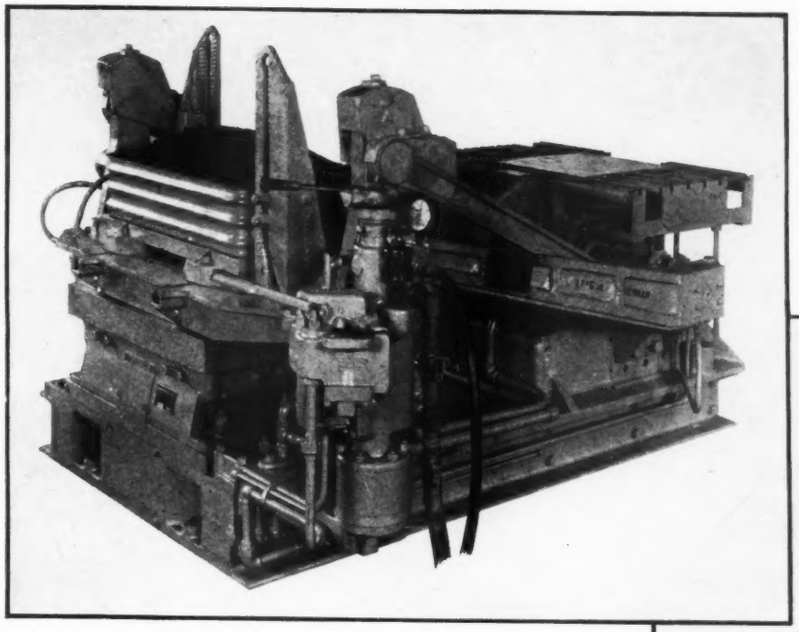
Air-Oil-Electric Controls Give High-Speed Cushioned Operation

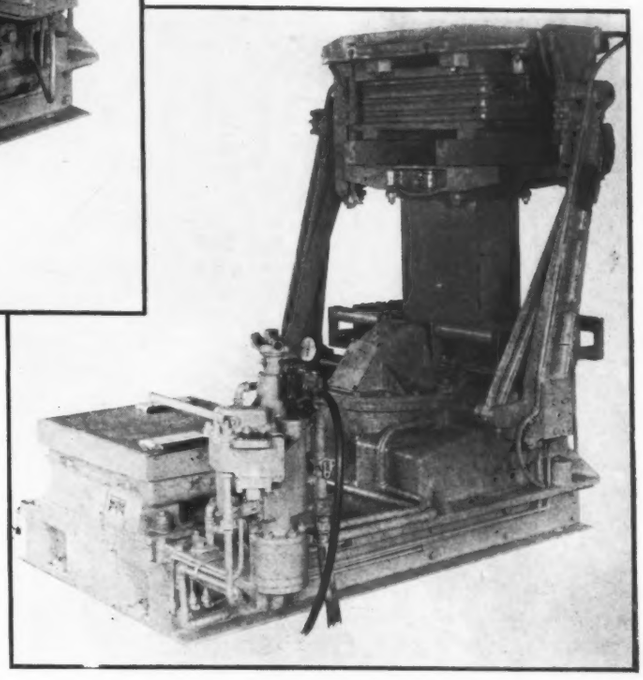
Though powered exclusively by air, the 1,500-lb.-series molding machines manufactured by the Herman Pneumatic Machine Company, Pittsburgh, Pa., are controlled by a combination pneumatic-hydraulic-electric system, in which the oil-controls operate on a principle somewhat similar to that employed in the familiar hydraulic door-check. The system is designed so that during the operating cycle high speeds are attained where permissible, but movements are smooth and cushioned where desired.

Jarring and vibrating mechanisms are


Cross-section of vibrator which is fastened in turnover plate
Tee slots for fastening clamps and equipment to turnover plate
Bronzed-bushed bearings
Turnover-plate leveling device
One-piece alloy-steel crank shaft
Close-fitting sheet-steel guards
Spring-suspended automatic air-locked equalizer device
Resilient material
Table plate sand guard
Automatic control valve permitting variable gravity drops in jarring table
Exhaust
Adjustable packing gland
Mechanical foundation consisting of completely enclosed shock-absorbing material
Jarring ram
Guide rods and bearings to secure accurate pattern draw
Electric timer graduated in min. and sec.
110 volt service lines
Start
Air-filtering device for jarring mechanism
Regulating valve
Metering pin effect for high-speed rollover safety feature
Rollover reservoir in base
Emergency stop
Rollover oil line
Solenoid-operated valve
Air Circuits
Oil Circuits
Rotary Valve Operating-Position Sequence
①-During jarring
②-Exhaust
③-Rollover
④-Raise drawing ram
⑤-Lock equalizer device
⑥-Vibrate and slow draw
⑦-Fast draw
⑧-Reverse rollover and exhaust
Pattern draw oil line
Pattern draw reservoir in base
Air line to flask clamps on turnover plate
Vibrator air line
Rollover air line
Pattern draw air line
Slow draw air line
Equalizing beam lock air line
Jarring air line
2-way valve with side outlet for operating flask clamps
Rotary valve
Air supply

Electric timer, started by pushbutton, stops jarring cycle at a preset number of strokes. Rotary air valve initiates subsequent operations but control of speed and cushioning of rollover and pattern-draw movements is inherent in hydraulic design, thus providing smooth, steady action





High-speed molding machine with flask filled, ready for jarring, is shown above. At right, both rollover and raising of pattern-draw mechanism have been completed

air-controlled; rollover and pattern-draw mechanisms are oil-controlled. An electric timer, started by a pushbutton, controls the jarring mechanism through solenoid-operated valve, stopping the action when the desired number of jolts to give the proper density of mold have been administered. During rollover, a high-speed safety feature—in effect a metering pin—automatically precludes sudden acceleration and deceleration by throttling the hydraulic fluid entering the rollover cylinder during the initial and final portions of the stroke.

The pattern-draw mechanism operates at either a slow or a fast speed, the former being obtained by means of an air-actuated hydraulic-throttling valve. The fast speed is used for the upstroke at the end of which a spring alignment device, called an equalizer and located on the top of the draw mechanism, takes up any irregularities in the flask and bottom board and is then locked in place by an air-operated device.

The slow speed of the draw mechanism is used to initiate the downstroke, while the vibrator simultaneously aids in separating the pattern and the mold. As soon as the two have been freed, the fast speed is brought into action and the mold is deposited on the conveyor. Another twist of the rotary valve returns the rollover plate to its original position, and the cycle is complete.

Large Glass Piping

Large glass pipes now being produced in sizes up to 4⅜ in. in diameter and 12 ft. in length are being applied in many designs such as heat exchangers, food machinery and chemical equipment. This has directed attention to the solution of a number of design problems previously not encountered with this material.

According to engineers of the Corning Glass Works, the design of glass pipe lines, for example, requires attention only to those factors considered in all well engineered designs regardless of the material used. Long straightaway runs, of course, must allow a greater degree of expansion for glass than for metals but this expansion can readily be accommodated by a simple expansion joint.

Proper alignment and support are also of importance. Corrections of alignment, however, both during installation and in subsequent operation, is facilitated by the inherent visibility of glass. "Pocketing" can be detected by inspection and slope can be adjusted to give complete drainage.

Indicative of what has been accomplished thus far is the fact that glass piping, from installations of but one ft. in length up to one of 20 mi., is now serving many industries. Such glass pipes are subjected to pressures from 50 lb. per sq. in. in all instances and up to 100 lb. per sq. in. in the majority of installations. Recent improvements in glass manufacture make them exceptionally tough and flexible.

Piping specialities, such as injector pipes, aspirators, and similar parts, can be designed in glass almost identically with their metal counterparts. The fused type of joint, shaping in the blast lamp, and grinding are substituted for the threaded, welded, or bolted metal joint and conventional cutting methods.

RANDOM JOTTINGS ABOUT NEW DEVELOPMENTS

With the exception of two case-hardened steel crimping wheels and several small screws, the "Fastnrite" machine produced by the Progressive Mechanical Corporation is assembled entirely of zinc alloy die castings. The device fastens sheets of paper together by crimping one edge, thereby eliminating clips, staples, pins, and glue.

* *

An all-steel, electric-arc-welded cabinet has recently been substituted for the wood cabinet originally used to house the Robotyper, the automatic typewriter for quantity production of personalized letters, which was introduced last year (*P.E.*, April 1936) by Automatic Business Machines Inc., Pittsburgh, Pa. Advantages gained with the new cabinet, which is formed of hot-rolled steel plate, are greater strength per lb. of weight, permanence, elimination of warping and shrinkage, and reduction of noise caused by vibration through the application of dampeners on all flat sides and surfaces.

Fig. 1—A skilled operator has a high regard, even affection, for a fine looking machine

BETTER APPEARANCE

Inspires Better Machine Production

W. J. BURGER
Works Manager, The Warner & Swasey Company

How a leading machine tool manufacturer starts with foundry control — grinds, primes and lacquers the castings in the foundry — and achieves a beauty of finish that promotes a high regard and better care of the machine by the operator

FROM the barber who brags to his mates about his pet razor, to the highest classes of skilled workmen operating large and intricate machines, there is more than mere respect for good machines and other tools of the trades. Respect of a skilled operator often borders upon high regard, even affection for a particularly effective instrument of his calling. In addition to productive efficiency, accuracy, and ease in handling, a machine may possess a distinction that sets it off from all of its neighbors by virtue of its form, lines, color, and general appearance. The fact that this high regard goes far to promote better care of machines, and consequently results in longer trouble-free service, is being recognized increasingly. Therefore, the modern designer pays more and more attention to clean design and high quality of finishes, these being points in favor of the machine that announce themselves at a glance.

During the last decade in particular, our company has given much attention to this phase of machine tool building, with the result that today a turret lathe leaving our plant presents a cleaner, better appearance than did a custom built limousine of former years. A glance at Fig. 1 shows the striking comparison between a machine of today and one of 1913. The modern design does not look like an assembly of parts, but, instead, it gives an impression as being a unit, complete in itself.

In the automobile industry the coming of lacquers gave the manufacturer the opportunity of improving beauty of finish and reducing costs at the same time. The durability of such finishes was early proven, and The Warner & Swasey Company adopted the lacquers while they were still relatively unknown or ignored.

It was not merely a matter of "using a new paint." Our whole finishing schedule had to be changed and in adopting the lacquers new and higher standards of quality were established. Because of

the nature of the new lacquer materials and the use of the spraying process, as great a thickness of cover as had been used with the former materials was no longer desirable. And because of the thinner coatings it became necessary to start from a higher quality of under-surface than was required formerly.

The attainment of finer under-surface begins in the foundry where every detail of the molding and casting process must receive careful attention. All molds and cores are heavily coated with graphite, and in some cases the finishing coats are laid over an under-coating of silica flour. In the large castings mold surfaces receiving metal are first carefully sprayed with a graphite solution which subsequently is slicked or brushed down to a smooth sheen. Molds are then baked and well inspected before pouring.

The important part that foundry control plays in the final finish obtained cannot be over-emphasized. Foundry conditions are governed largely by results in the cleaning and priming rooms, and as soon as even the most minute imperfections in surface show up there, practice is altered for improvement.

So well are conditions controlled that even in the bed castings for the large *A*-type Warner & Swasey turret lathes, in the making of which some 10,000 lb. of metal are poured in approximately 40 sec., the resulting casting has a clean, smooth surface.

Unique in Warner & Swasey's finishing method is the practice of completely priming and ground-coating all castings at the foundry. Immediately after leaving the molding floor, the castings are taken to the cleaning floor where air-operated chipping hammers remove all flashes and burrs. Air-driven grinders fitted with wheels of definite specifications then smooth any remaining imperfections or blemishes. In Fig. 3 is shown a typical bed casting being surfaced by this method.

As soon as the grinding is complete, the casting is transported to a large spray booth where it is completely primed with a lacquer undercoater. Any small surface blemishes then appearing are filled with pyroxylin putty, applied by hand by usual methods.

A rubber applicator is then called into service, and all grinder and file marks are covered by pyroxylin filler. A second very thin coat of filler, immediately hand-brushed over the first coat, completes the ground-surfacing operation. After a twelve-hour period, during which all material hardens thoroughly, the entire casting is sanded and rubbed to a smooth surface. This operation removes all excess material except that which remains in such depressions as file marks. The coating of filler over the metal is quite thin, thereby giving an exceptionally tough finish which withstands all subsequent factory handling with only minor touch-up.

Before leaving the foundry, each casting receives two coats of lacquer undercoater over the sanded surface. It is interesting to note that all machining and handling in the manufacturing process is done after the major portion of finish has been applied. The machining and assembly of each turret lathe proceeds in the usual way, since the toughness of the finish already on the pieces makes special care in handling unnecessary.

After each turret lathe has been tested and checked, it is washed down with a petroleum solvent to remove all oil and grease which has accumulated during the machining process. Any additional scratches to which the surface may have been subjected are filled with pyroxylin putty and sanded smooth. The portions of the lathe that are not to receive any further finishing are then thoroughly masked with heavy grease and tape, so that they will not be exposed when the remaining surfaces are being reached by the spray gun. With all masking and surface preparation completed, the machine is transported to a large spray booth and two continuous coats of lacquer enamel are applied. All upper surfaces, such as the top of the geared head and the turret saddle or ram, receive a third finishing coat of the lacquer enamel.

The drying time required for the material used is so short that unmasking may be started as soon as the finishing coats have been completed, and the lathe can be shipped to the customer immediately after final inspection.

One of the most noteworthy observations to be made in this picture of the machine tool finishing problem is that each piece of equipment is ready for the customer after about three man-hours of work, following the final run-in stand inspection. Inbuilt accuracy and fineness of finish of mating parts are unchanged, and the former relatively long period in the finishing process is eliminated.

Ten years' experience in the Warner & Swasey plant has shown that, because of the toughness of the new finish, the damage to the coatings during machining is far less important than the damage to machined surfaces that might result from subsequent painting operations.

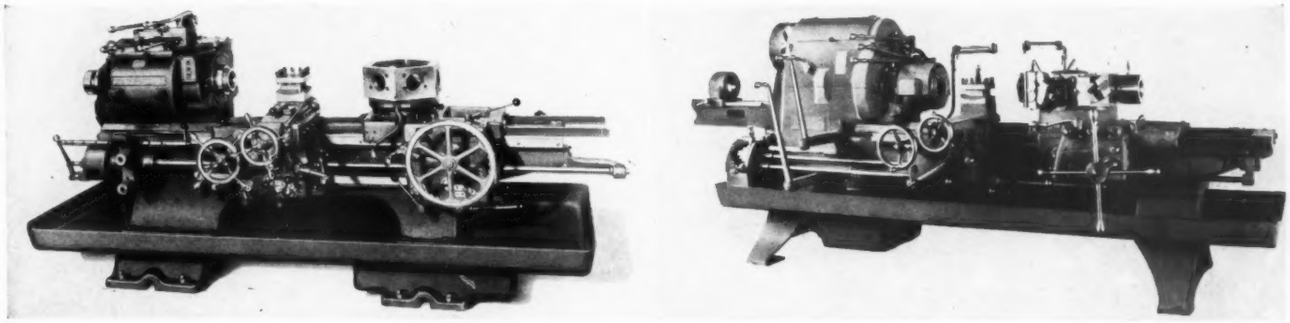


Fig. 2—Twenty-five years of progress — from a grotesque assembly to a well-proportioned attractive unit with high-grade lacquer finish

Fig. 3—After chipping to remove all flashes and burrs, the castings are ground in preparation for priming lacquer

AGGREGATION *or* COMBINATION

A Question of Patentability

H. A. TOULMIN, JR.
Patent Attorney

Many costly law suits have resulted because a designer did not know the legal distinction between an aggregation of elements or parts, which is never invention, and a combination, which is invention if it accomplishes something new and useful. The writer, author of "Invention and the Law," and numerous other books on patent law, explains the distinction

IT IS not so fatal, involving only a waste of time, if the patent office quite properly refuses a patent on a design that is merely an aggregation of parts. But the patent office by mistake sometimes issues a patent on an unpatentable "invention". Later, the owner of the patent sues another for infringement, only to find that his "invention" is not invention at all and that his patent is therefore void. Some of the most expensive and heart-breaking patent litigations have ended like that. For example: A patent was issued to cover a "combination" of elements for the automatic operation of a stoker. It included a stoker, a thermostat to control the stoker and a time device to start the stoker regardless of room temperature, so that the fire would not go out for lack of fuel.

Later, a competitor put on the market a similar group of devices to accomplish the same purpose. The patent owner sued on the grounds of infringement. He lost, the court holding that his patent was invalid. "The union," said the court, "is a mere aggregation unless the elements, by their united action, perform some function which they do not separately discharge." It is, incidentally, interesting to sense how the courts look upon aggregations which involve no creative intellectual achievement, as evidenced by the fact that in the vast majorities of decisions the courts refer to "mere" aggregation.

Typical of "mere" aggregations is the grease service tank, the patent on which was voided by the court. It included a series of pump or grease-gun supports, a corresponding series of pumps and grease guns, a series of indicia upon the rack close to the supports, each mentioning a particular part of the automobile which needed specialized lubrication, a series of identification marks on the pumps and a corresponding series of identification marks on the racks near the supports for identifying each pump with its support.

Said the court about this: "There is no co-action between the support and the pumps, or between the pumps and the legend on the rack. It is the same as a carpenter's cabinet for augur bits, a druggist's cabinet or a hotel-keeper's rack for room keys . . . the old elements are brought together, not in the co-operative union of a true combination, but in the forced relationship of a mere aggregation."

Inventors frequently go astray through holding the wrong notion that whether a device is simple or complex is the test of whether it is an aggregation or a combination. Nothing could be more erroneous. Some very simple machines are combinations and some highly complex ones are mere aggregations. For instance, one designer worked out an apparatus for mixing and transporting concrete. It consisted of an upright chamber in the top of which was an opening for introducing the material, equipped with a door to close the opening airtight; a hopper-shaped bottom to the chamber, discharging into a delivery duct; a pipe through which compressed air entered the chamber above the mass of concrete to propel it into the duct; and another pipe delivering compressed air at or near the discharge or lower end of the hopper; etcetera, etcetera. It was complicated enough, to be sure—but, it was not patentable because it was an aggregation of known devices each acting in its regular way.

It has frequently been decided that to put any number of old elements together which evolve no new co-operative function and produce no new result other than convenience and economy, does not constitute invention because the device remains an aggregation of elements. One often cited instance is that of a washing machine and wringer geared together to permit simultaneous washing of one batch of laundry while the preceding batch is wrung out. The court said:

"No new function evolved from this combination. The new result, so far as one is achieved, is only one which arises from the well-known operation of each of its elements. In the gearing specified every element is old. The operations of the wringer and washing machine, although simultaneous, are independent one of the other. The control of the operation of the wringer is by an old and well-known method. From the co-operation of the elements here brought together no new result involving the exercise of the creative faculty is achieved. . . . Superiority does not make an aggregate patentable . . . the aggregation of elements may be likened to the operation of the machines in a factory by power applied from the same line-shaft, each operation contributing its separate part to the production of a given result." The patent was held to be invalid.

On the other hand a true combination may be as simple as may be and still be patentable. To the layman there may seem to be much in common between the grease-gun rack already described, which was an aggregation, and the metal filing cabinet invented by Rand which was shown to be a true combination.

This device consists of flat drawers or panels containing index cards adapted for visible indexing. A previous patent had covered a case containing drawers which could be tilted when fully withdrawn but which, due to the method of suspending the drawers, made it practically impossible to tilt another drawer simultaneously. The Court held that the Rand invention contained certain elements which were old, but that the use of extendable slides with the old elements produced a novel and highly useful result—the simultaneous inspection of several panels. It was declared to be a patentable combination. Merely because the elements are old is no bar to the

patentability of a combination—provided that acting together they accomplish a new result which is more than the mere sum of their ordinary results.

Such a case is that of a combination of high-speed water turbine with adjustable runner blades to co-operate with the adjustable guide vanes. The fundamental object of the combination was to regulate the capacity of the turbine to suit the amount of power it is called upon to deliver, thereby enabling the turbine to work at less than its maximum power with the use of only a proportionate amount of water. Regulating devices used prior to this invention, it was asserted, had the disadvantage of greatly reducing the efficiency of the unit when operating at less than full capacity.

This invention consisted of methods by which the inlet and outlet angles and passages of the runner blades could be adjusted automatically with variations in the angle and velocity of water admitted to the runner by the movable guide vanes. For each position of the movable guides there was a predetermined angular position for the runner blades. It was held to be a combination.

Examples of unpatentable aggregations are a paste jar having one compartment for water and one for paste; a machine bringing together means for grouping, feeding, opening, moistening and sealing envelopes; two machines on a single bedplate for performing succeeding operations on a product; several tools on the turret of a turret lathe; a railroad car together with certain machinery carried by the car.

From earliest days the courts have been practically unanimous in their feeling about aggregations and combinations. From the many decisions it is possible to select a few which should enable the designer to know whether his brain child is one or the other—and even to suggest ways in which he may be able to change a machine which he is designing from a mere aggregation to a combination. Some of these decisions are here quoted verbatim:

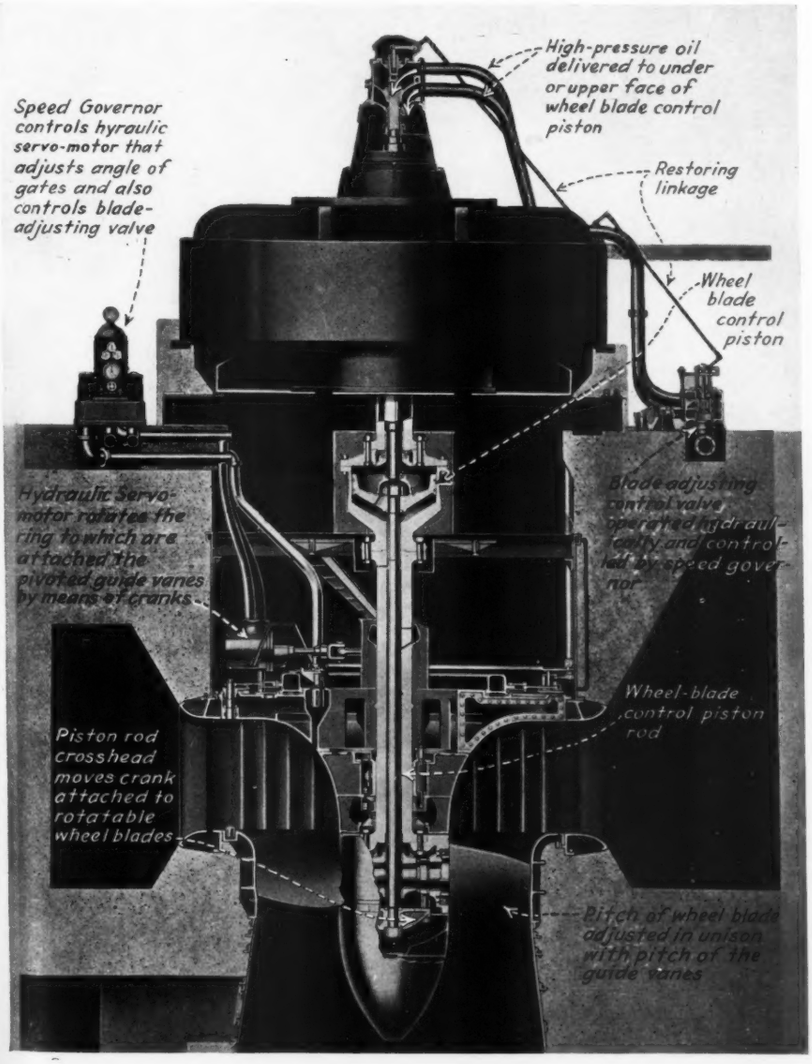
"It may be laid down as a general rule, though perhaps not an invariable one, that if a new combination and arrangement of known elements produce a new and beneficial result, never attained before, it is evidence of invention."

Again: "The combination to be patentable must produce a different force or effect, or result in the combined forces or processes, from that given by their separate parts. There must be a new result produced by their union; if not so, it is only an aggregation of separate elements."

One other clear and complete statement of the views of the Supreme Court of the United States: "It must be conceded that a new combination, if it produces new and useful results, is patentable, though all the constituents of the combination were well-known and in common use before the combination was made. But the results must be a product of the combination and not a mere aggregate of several results, each the complete product of one of the combined elements. Combined results are not necessarily a novel result, nor are they an old result obtained in a new and important manner. Merely bringing old devices into juxtaposition and there allowing each to work out its own effect without the production of something novel, is not invention. No one by bringing together several old devices without producing a new and useful result, the joint product of the elements of the combination, and something more than an aggregate of old results, can acquire a right to prevent others from using the same devices, either singly or in other combinations, or, even if a new and useful result is obtained, can prevent others from using some of the devices, omitting others, in combination."

And finally, let me cite the remarks of Judge McDermott, who stated sound law in non-legal figures of speech, when he said:

"I think of a foot-ball team as a combination: one passes, one receives, another blocks, another runs and still others hold the line. Eleven men are doing different things, each in his own way, and not always simultaneously; yet they are working to a common end, to advance the ball; and they co-act as a unit. I think of a track team as an aggregate: one runs, another hurdles, another jumps, another throws. They all work for a common general end —to amass points for their alma mater; but there is lacking the vital spark of co-operation or co-ordination. They work, not as one unit, but as several."


High-pressure oil delivered to under or upper face of wheel blade control piston
Speed Governor controls hyraulic servo-motor that adjusts angle of gates and also controls blade-adjusting valve
Restoring linkage
Wheel blade control piston
Hydraulic Servo-motor rotates the ring to which are attached the pivoted guide vanes by means of cranks
Blade adjusting control valve operated hydraulically and controlled by speed governor
Wheel-blade control piston rod
Piston rod crosshead moves crank attached to rotatable wheel blades
Pitch of wheel blade adjusted in unison with pitch of the guide vanes

A high-speed water turbine with adjustable runner blades to cooperate with adjustable guide vanes was held a patentable invention because it is a combination that achieved a new result

Fig. 1—One of the forward bedplates fabricated for the Sun Shipbuilding and Drydock Company as a part of the frames of Sundoxford diesel engines. This bedplate weighs 48,980 lb., is 24 ft. long, 12 ft. 8 in. wide and approximately 5 ft. high

SHALL IT BE WELDED?

If So—How Designed?

E. J. CHARLTON
Engineer, Lukenweld, Inc.

In answering the first of these questions, the author discusses considerations that govern the material and type of construction to be selected, and then gives some criteria for properly engineered welded structures

THE use of welded steel parts as supporting, housing and connecting members in machines of all types has reached the point where it has become a definite factor to be considered by the designer in his determination of what material and type of construction he shall use to perform these functions in the machine that he may be developing. This applies whether it be an entirely new product or a redesign. Naturally there are some definite considerations that will govern the decision as to whether welded steel is the proper answer. These considerations naturally group themselves into two divisions, economic and engineering requirements.

It is presumptious to attempt to set up a rigid mode of thought regarding either the economies or the engineering involved. This is impractical since the types of possible structures and future developments in methods and materials are infinite in their variety. In its rapid development during the past few years, the design of fusion welded steel constructions however has progressed to such an extent that certain general fundamentals have been established, even though some of their aspects are not entirely undisputable.

Generally, if the design of the structure under consideration includes a large number of pieces in proportion to its weight, if its production involves the necessity of many operations and special handling and working of the metal, it is unsound from the economic aspect to design it for fusion welding unless it is judged that the value of weight reduction warrants it. If the design does not provide proper accessibility for welding, considering the service requirements on the part, and this feature cannot be corrected by approaching the problem from

a new design angle, it is unsound from the engineering aspect to design it for fusion welding.

As an example of "accessibility for welding", consider it as illustrated in Fig. 1, which shows a portion of a bed for a large opposed piston type engine. Here can be seen the openings provided in the webs that form a part of the main bearing support, cut for the purpose of permitting the welding of the inside joints in the boxed member. The circular openings in the sides of the formed plates supporting the bearing castings of the housing shown in Fig. 2 are provided for the same purpose.

Accessibity Openings

The provision of such access openings we believe to be essential in pieces such as this, considering their requirements. If the joint is not welded on both sides the completed part is analogous to a casting with an eccentric cross section at the points where the metal contour changes its direction. In addition to this eccentricity there is also the very bad reentrant shape caused by the portion of the plate unfused by welding as shown in Fig. 3C. Lastly, at best the joint does not have the easing curve produced when there is a weld fillet on both sides, as in Fig. 3D. It is to be remembered that a welded joint is not a mechanical connection as in a riveted structure; in fact, when welding is completed it ceases to be a "joint" in the true sense of the word. Metallurgically the two parts become one piece as does the entire structure when completed.

The implication is not intended that the designer should consider every welded joint with the above factors in mind. However, he should grasp their significance because certainly they are of major importance somewhere in the design of any structure to be subjected to repetitive stress. It is well recognized that the joint shown in Fig. 3D does not fill the requirements occasioned by certain types of stress. The necessity for cleanliness and absolute elimination of internal voids can well be imagined in joints subjected to severe loading. Steps are taken to insure this as evidenced by the elaborate methods in use today for the inspection of such joints. The question of concentration of stresses set up in the welds illustrated, which approach the extreme under certain conditions of loading, has been widely discussed and graphically represented in photo-elastic studies.

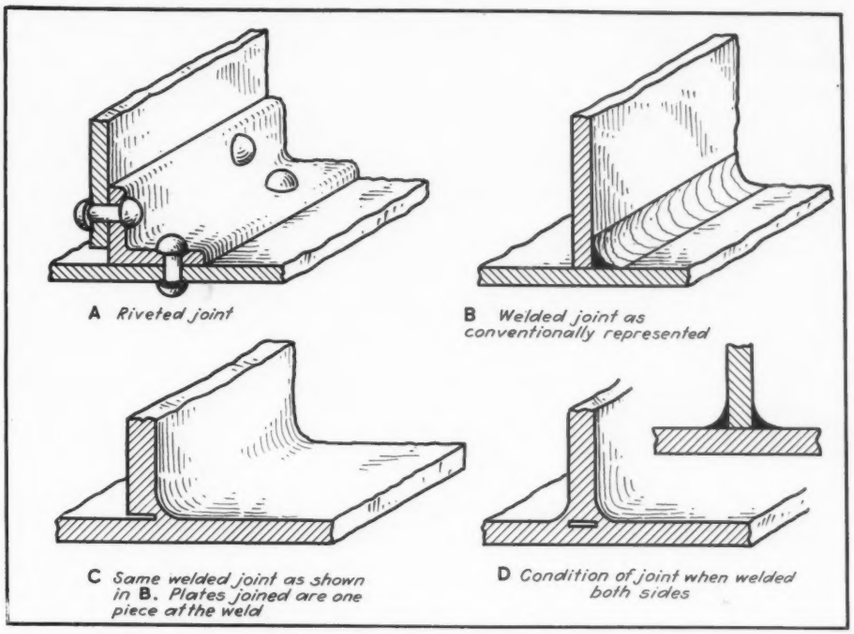

A Riveted joint
B Welded joint as conventionally represented
C Same welded joint as shown in B. Plates joined are one piece at the weld
D Condition of joint when welded both sides

Fig. 3—A joint welded on one side only, as at **B**, *is in no sense comparable to a riveted joint as at* **A**. *At* **C** *is shown why a weld on one side only is eccentrically loaded, is subject to fatigue failure because of the reentrant shape, and lacks the symmetrical easing curves necessary for uniform stress distribution*

Concerning the economic justification of a design involving a large number of pieces in proportion to its weight, consider the frame shown in Fig. 4. It is for the Sperry Rail Service's new rail-flaw detector cars. In addition to performing the usual functions as a truck frame, the structure carries recording electrical apparatus for the detection of fissures and flaws in rails. Here weight reduction is of paramount importance. The welded design calls for 234 pieces of Cromansil steel to be assembled by welding, many of the pieces requiring special handling and forming operations. As can well be imagined from a study of the shape of the piece there are also some production problems involved in its welding. However, considering the importance of weight, the design of this part in welded steel is eminently proper. The frame is about 15 ft. in length and 7 ft. 6 in. in width and weighs about 3,970 lb. before machining, contrasted

Fig. 2—A welded steel gear reduction housing weighing 12,400 lb., made for the Standard Dredging Company. It illustrates the application of three fundamental considerations—use of steel castings, formed plate construction and the provision of accessibility openings

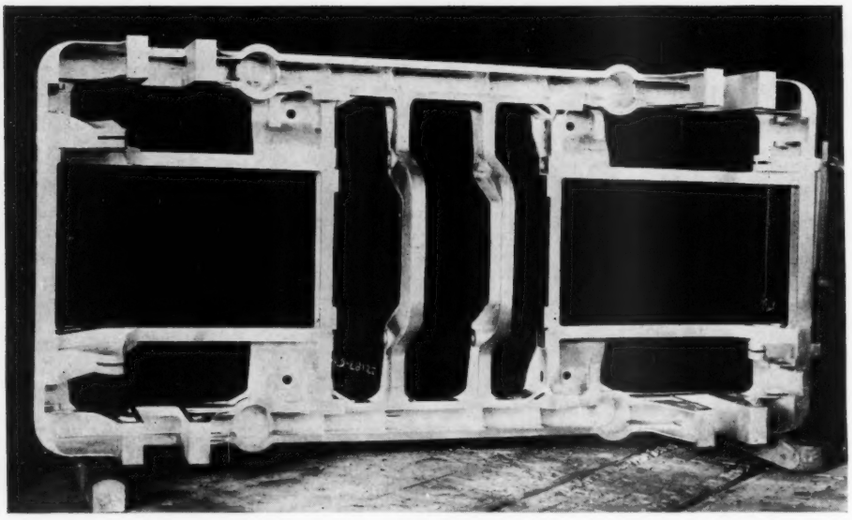


Fig. 4—An example wherein reducing the weight from 6,000 lb. in cast construction to 3,970 lb. in welded construction justified welded design, although the assembly requires 234 pieces

with a minimum estimated weight of 6,000 lb. if produced by the conventional method.

When a design involving the features discussed above occurs as a unit of a larger assembly and weight economy is not of first importance, the answer, for the present, is to cast the unit that embodies such difficulties and use it as a part of the welded job. Examples of this may be noted in the main bearing housing proper of the bed shown in Fig. 1, in the dredge drive reduction housing shown in Fig. 2, in the pipe threading machine bed shown in Fig. 5, and in the truck frame shown in Fig. 6. The castings used in such instances are usually of such size as to be readily produced in electric furnace steel, which is desirable. The castings in the truck frame, Fig. 6, may not be readily discernible. They consist of the entire journal guide section, including the brake cylinder supports, at the four corners of the frame; the upper flange intersection of the cross members with the side members, which is complicated by a number of bosses on its top surface; and the slack adjustor support which can be seen on the extreme right of the figure.

There was unquestionably quite a pattern expense involved in the design of the truck frame shown in Fig. 6. However, its importance was vastly minimized because of the quantity of frames built. This is in contrast to the design of frames shown in Fig. 4. These latter frames, built for a special purpose and only a few in number, contain no castings in their design.

There are some rather interesting economic factors involved in the application of welded steel to the dredge cutter drive reduction housing shown in Fig. 2. As the engineer progressively develops the design of his machine or equipment he attempts to standardize the elements of his mechanical units in so far as possible. In every one of these drive reduction housings, the cast steel bearing pieces built into the upper part of the housing are of the same dimensions at a particular point in the reduction. But because of the variation in position and type of support in different dredges, standardization of the complete housing is not possible. Considering that the dredge is out of service when awaiting parts required for its reconditioning and considering the length of time it takes to make an individual pattern and cast a housing, it can readily be understood that a design that could be furnished quickly for different dredges was highly desired.

In view of these factors, a housing fabricated of structural shapes and plates riveted together is a possibility but inadvisable because of the maintenance problem created by the dynamic forces imposed on the structure, as well as the requirement of oil-tightness. A plate-welded structure as shown in the photograph is the solution of the problem. This housing is approximately 14 ft. x 8 ft. x 4 ft. overall. Metal thickness generally is $\frac{5}{8}$ in. to $\frac{7}{8}$ in. The structure weighed 12,500 lb. before machining. Obviously, if such a unit replaces a cast iron housing, a weight reduction is possible as a result of the superior quality of the material in the welded structure, and the better distribution of the metal in the welded design.

Another factor to be kept in mind in deciding whether or not to use welded steel is the thought that in the case of a structure that is part of a totally new mechanism, if welded steel is used the designer, after he has seen the machine in operation, can make extensive or complete changes in his design without regard for investment in pattern equipment. At the same time the welder has an opportunity to study the general features of the part with the object of suggesting possible modifications to set it up for production on a quality basis.

Frequently, after it has been decided to use welded steel the designer proceeds with his overall design on the basis of criteria applying to materials formerly used, up to the point of the design of the welded structure itself. It can be demonstrated that, if the "feel" of the possibilities and limitations of welded steel is carried through the "thinking out" stage of the entire machine, a cleaner and better design will result, uncompromised by a mode of thought set up by the influence of the types of construction formerly in use and which have their own peculiar limitations.

To illustrate what is meant by a "compromised mode of thought", when welding was first introduced, great emphasis was placed on the many advantages to be gained by "replacing rivets with welding". For many years technical meetings were frequently devoted to "welded versus riveted construction," and pros and cons were argued with fiery fervor. Examples of "welded designs" were thrown upon the screen showing how gusset plates and rivets were eliminated by simply welding the

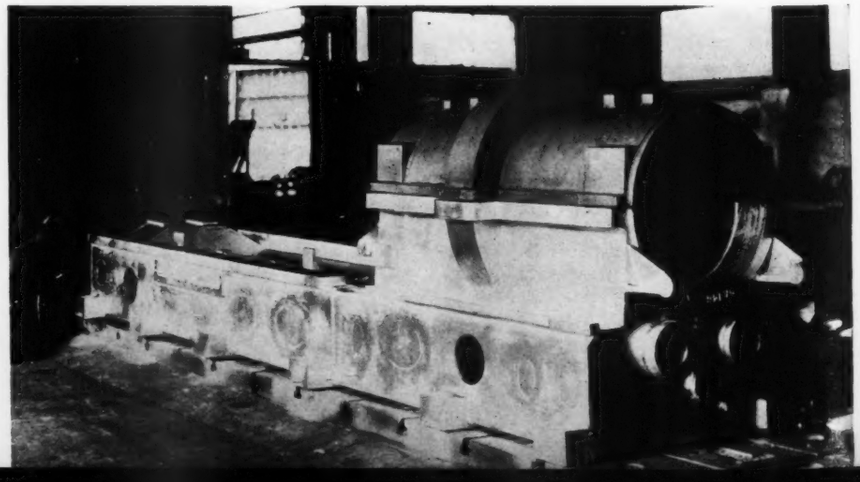


Fig. 5—Numerous steel castings, including the ends of the bearing cap and the ends of the bearing to which the cap is bolted, were incorporated in this welded steel bed for a pipe threading machine built by Landis Machine Company. The bed, box type for torsional rigidity, contains oil tight compartments

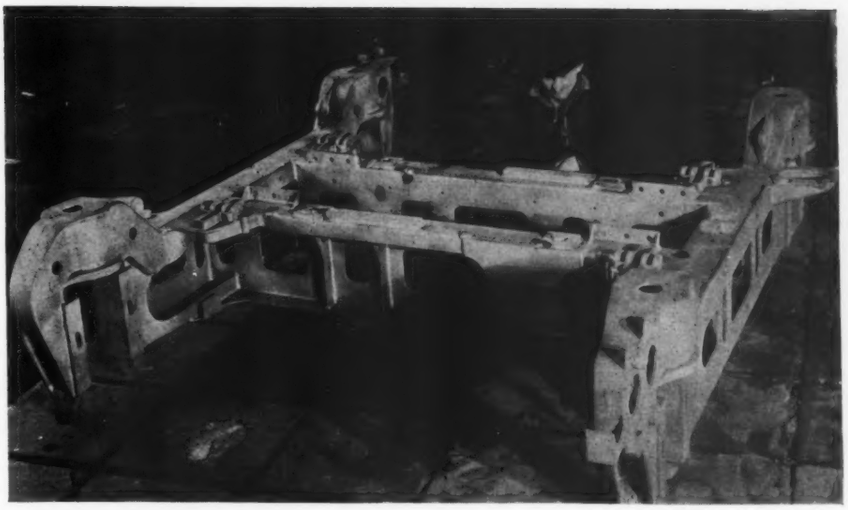


Fig. 6—Completed truck frame for a multi-section car built by St. Louis Car Company. Many of the pieces are electric-furnace steel castings

channels and I-beams together. But in every instance it was the joint that was being discussed and not the design of the structure.

It is therefore only natural that when fusion welding was carried over into the field of mechanical design, the conception that welding was primarily applicable to joining structural plates and members was also carried over. Frequently rolled shapes were found in a welded design for a machine part where they are unjustifiable from both economic and engineering standpoints. After all, these shapes were designed and sized originally for specific purposes. Even when used in their natural sphere compromises must often be made with sizes available; compromises possibly detrimental to the overall weight requirements of the structure.

Practically all rolled shapes have been evolved with regard to their suitability for riveted construction. Rivets require the existence of flanges for load transmission. Why build such flanges unnecessarily into a welded structure? An illustrative contrast is shown in Fig. 7. At *A* is shown a portion of a bedplate consisting of plates formed on a bending brake. Plates formed in such a manner are readily available commercially. At *B* is shown a portion of the same bedplate as designed to be made of rolled channels with a flat plate on top. Consider the relative merits of the two designs from the standpoints of appearance and amount of welding required. Such designs of course are influenced by the size of bending equipment.

It is to be suspected that sometimes a designer approaches the layout of a welded assembly with a desire, subconscious perhaps, to use as a start some shape with finite dimensions. He will usually end up proud of his creation, basing the most of his pride on the ingenuity displayed in having worked

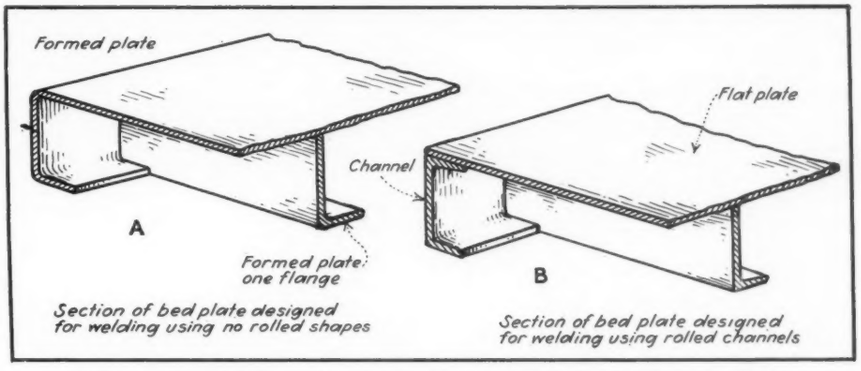

Formed plate
Flat plate
Channel
A
Formed plate one flange
B
Section of bed plate designed for welding using no rolled shapes
Section of bed plate designed for welding using rolled channels

Fig. 7—The design at A is not subject to the restrictions and requirements that pertain to rolled shapes. Comparing it with the construction shown at B, *note the rounded corners. smaller amount of welding and the absence of the superfluous upper flanges of the channels*

these definite rolled shapes into all manner of applications as elements of his welded part. Usually the result is pretty much of a compromise with good practice throughout and one will undoubtedly also find such a piece to be a veritable sponge of lap joints and welds of a type detrimental to the continued service of the parts in a machine embodying repetitive loading conditions.

This by no means is intended to convey the idea that there is no application for shapes in welded machine parts. An example of their advantageous use is shown in Fig. 8. This relatively large bedplate is composed almost entirely of H-beams with no superstructure or pads for machining required except at the one point that is shown in the illustration. Obviously building up this bedframe from plate alone would involve much more welding and a greater number of pieces. This indicates more assembly difficulties and consequently less accuracy in its final dimensions could be expected.

In approaching the design of any machine it is first necessary to develop the functional shape required and the general dimensions. The latter will be determined by the size and capacity of the machine being designed. Each of the various elements of the machine will have its own particular function or purpose, such as bedplate, housing, bearing, connecting rod, cylinder and other parts. Each of these elements and portions thereof will be subjected to loads of a certain character and magnitude.

(*Concluded in August number*)

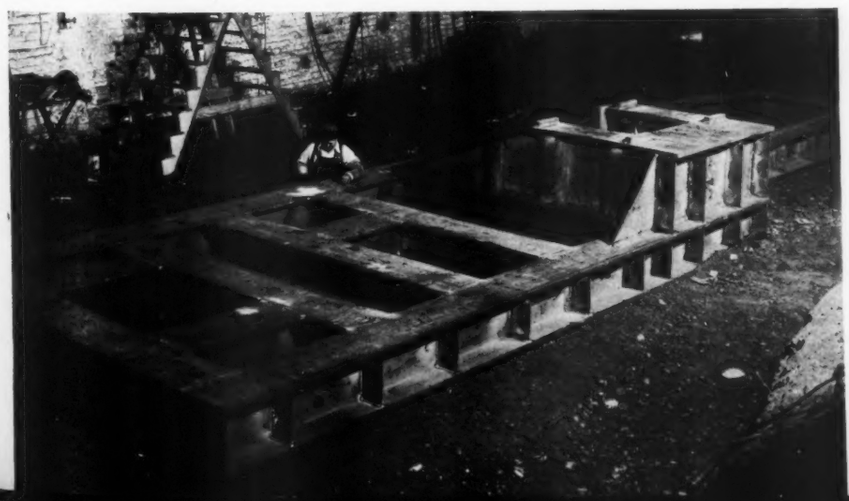
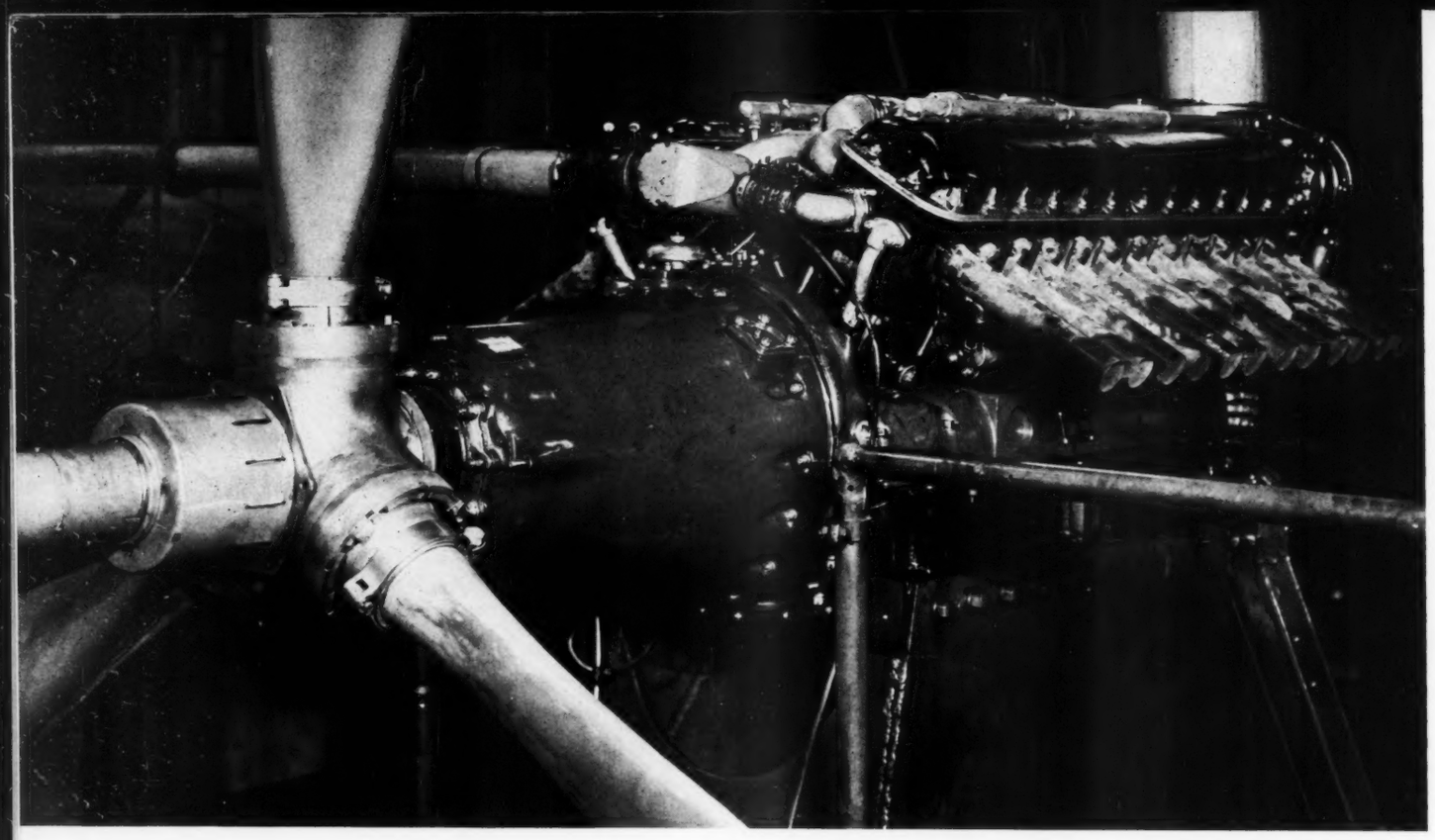


Fig. 8—A welded design wherein rolled shapes have been used to advantage—a welded steel sub-base weighing approximately 34,100 lb., made by Lukenweld for the B. F. Goodrich Company



Allison engine is here shown on test block after receiving U.S. Army Air Corps approval for 1,000 hp., 150 hr. test

PACKING A 1,000-HP. WALLOP

Into a Compact Aircraft Engine

New Allison engine, weighing only 1.28 lb. per hp. and having frontal area of less than 6¼ sq. ft., combines variety of interesting and novel design features, such as chemical cooling, and ingenious camshaft, supercharger and propeller-shaft drives

FIRST of its type to pass the U. S. Army Air Corps 150 hr. test for engines of 1,000 hp. normal rating or larger, the new power plant developed by the Allison Engineering Division of General Motors Corporation departs considerably from recent design trends in the aeronautical field. It is a chemically cooled, 60-deg. V-type twelve cylinder engine instead of the widely used air-cooled radial type which in recent years has contributed so greatly to the progress of American aviation.

As its rated horsepower indicates, the engine is big. Yet, as shown by the accompanying illustrations, it is compact. Approximately 95 in. long, 51 in. high and 29 in. wide, overall, it has a frontal area of less than 6¼ sq. ft. and weighs but 1.28 lb. per hp. Its displacement is 1,710 cu. in. Packing all of this power into so compact a unit obviously involves considerable design ingenuity. The details of its construction, many of which are truly unique, will therefore be of interest to designers.

Probably the first aircraft powerplant specifically designed for chemical cooling, the engine uses ethylene glycol having a boiling point of 387 deg. F. The rates of coolant flow and the temperatures at all points around the cylinders, valve seats, and spark plugs were carefully determined by experiment so that uniform cylinder and head temperatures are obtained.

The way in which chemical cooling has been provided makes the engine design very flexible as to adaption for fuels of higher octane ratings as well as permitting ready adjustment of radiator requirements to meet compression ratio and altitude demands for particular installations. In addition, the flexibility of the cooling system makes it possible to use the engine for either tractor or pusher installations without change in cooling efficiency.

The engine is made up of a cast-aluminum upper and lower crankcase and two six-cylinder blocks, each a single aluminum-alloy casting containing the combustion chambers and valve mechanism. Steel cylinder barrels are fitted into the blocks.

The valves, of which there are four to each cylinder, are driven by an overhead camshaft completely inclosed and flooded with oil. The valve mechanism is accessible by means of a single cast-magnesium-alloy cover extending the length and breadth of the cylinder head. Valve seats and valve guides are pressed and shrunk into the machined cylinder head castings. Exhaust valves and valve seats are stellite-faced.

Each of the two cylinder-block assemblies are connected to the upper half of the crankcase by 14 long stud bolts extending through the head and into the case. This construction results in the power forces' being transmitted to the crankcase which is stiffened by the truss construction formed by its combination with the cylinder heads and barrels.

The engine drives the propellor shaft through a built-in reduction gear of 2:1 ratio. The reduction gear together with the propellor shaft are incased in a single aluminum-alloy casting which forms the nose of the engine.

The reduction gear consists of an internal spur gear which meshes with a pinion splined on the crankshaft. The internal gear is bolted to the propellor shaft by a flange which is integral with the shaft. A large single-piece steel-back bronze bearing completely encircles the external circumference of the internal gear. This type of reduction gear, it is claimed, results in an unusually compact, light-weight and sturdy design.

The propellor shaft assembly consists of two hollow shafts concentric with each other. The inner shaft transmits the torque of the engine and the outer shaft absorbs the bending stresses produced by the propellor. Thus the inner shaft is subjected only to torsion, the outer shaft only to bending.

An accessory housing is mounted directly on the rear of the crankcase. A magnesium-alloy casting, it contains the centrifugal supercharger used with the engine, together with the drives for the camshaft, coolant pump, fuel pump, vacuum pump, oil pump and generator.

The overhead camshaft is driven by beveled gears through the medium of a long slender shaft, in the upper part of the crankcase, which is driven by the reduction gear at twice engine speed. This long shaft has relatively high flexibility, resulting in a valve-actuating mechanism free from torsional disturbances.

The supercharger is driven at 6.75 times the crankshaft speed. The impeller shaft is supported on two steel-back lead-bronze floating bearings claimed to provide unusually trouble-free supercharger operation in spite of the high speed involved. The supercharger is also driven by the long flexible shaft which drives the camshaft and this design obviates the need for clutches usually required to take care of the effects of rapid changes in engine speed.

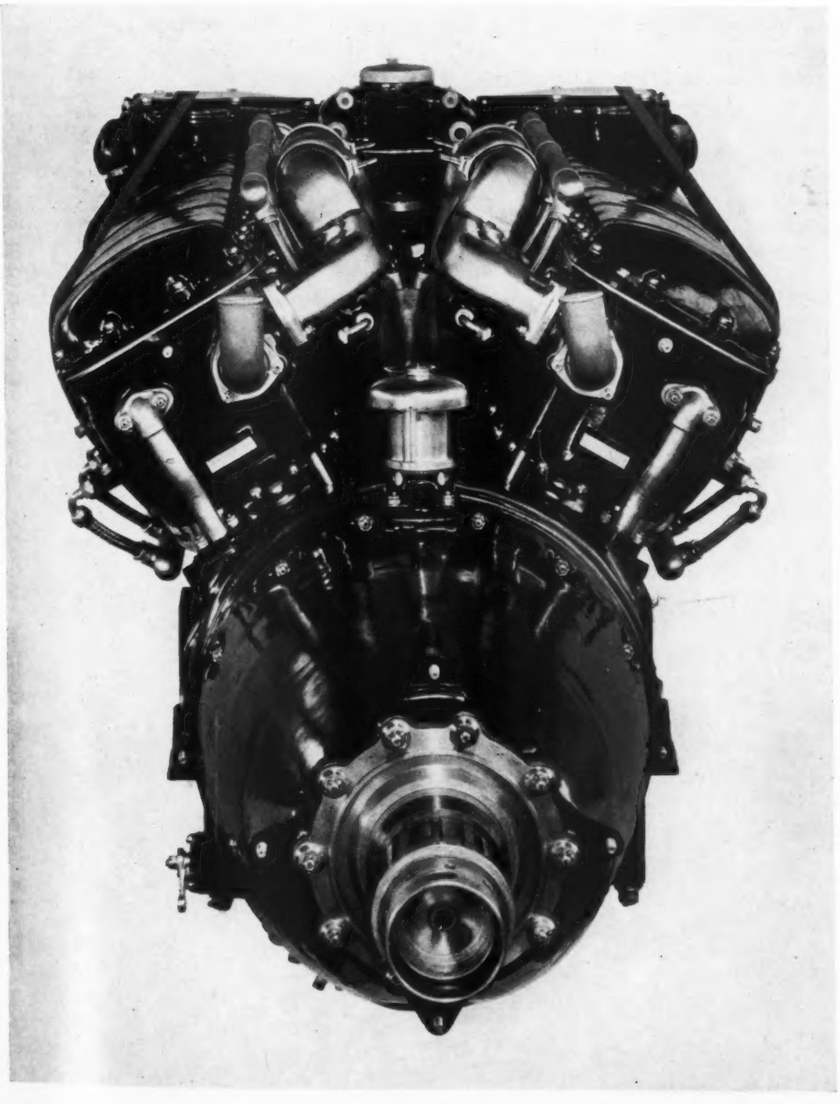
The crankshaft is of the conventional six-throw type, all surfaces of which are lapped or polished. The crankshaft journals are hollow and are fitted with removable aluminum-alloy plugs. Counterweights are welded to the forged shaft. The propellor reduction-gear pinion, as previously mentioned, is splined to the front end and a spur gear is splined to the rear end for the purpose of driving the oil pump, coolant pump, fuel pump, vacuum pump and generator. The engine starter also operates through this latter gear. A vibration friction dampener is located at the front end and a dynamic torsional balancer at the rear. These devices permit a large range of overspeed without detrimental vibration.

Pistons are machined from aluminum-alloy forgings and the underside of the piston heads are grid-ribbed to facilitate cooling. Connecting rods are of the forked and blade type, machined and polished all over. Two rods are mounted on each crankpin with a single split steel-back bearing faced with lead-bronze inside for the crankpin bearing and outside for the blade rod bearing.

Mounted on the rear of the accessory housing is a single four-barrel downdraft carburetor with automatic mixture control. The fuel-air mixture is supplied to the supercharger which delivers it to the ramming-type manifolds. The manifolds are equipped with grids to prevent back-fire flames from reaching the supercharger.

Ignition is supplied by one fixed-timing high-tension double magneto. Two separate camshaft-driven high-tension distributors are used, and two spark plugs are provided for each cylinder. When the engine is inclosed in a tight cowl, a blast of cooling air for the exhaust plugs is provided by means of a light aluminum-alloy manifold.

Back of all these design details is the engineering thought leading to the development of this V-type chemically cooled engine. The small frontal area of this type of engine, according to Allison engineers, permits ideal streamlining of the plane, which, in turn, can add five or more per cent to the speed of the craft for the same expenditure of power. Chemical cooling, they point out, makes it possible to obtain greater heat transfer to the air with minimum drag, since the necessary radiators can be located where the desirable volume of air can be obtained with less expenditure of power, thus making more of the engine output available for useful work.



Head-on view of the Allison engine emphasizes its small frontal area and trim construction

NEW DESIGN DATA

On Cu-Al-Ni Alloy

Recent information in handy reference form on uses and properties of the non-ferrous alloy of nickel copper and aluminum

NEW and revised data pertaining to the non-ferrous alloy of nickel, copper and aluminum known as "K" Monel have recently been compiled by the Development and Research Division of The International Nickel Company, Inc. for the use of designing engineers. Although the curves and tables given here are to some extent the same as previously published, all of the data has been rechecked, the figures modified where necessary, and a considerable amount of new information has been added.

The outstanding properties which make the use of this material desirable for numerous applications in the design of machinery and equipment are its resistance to corrosion, to abrasion and to pitting in salt water; also its hardness, strength, high modulus of elasticity, low rate of heat transfer, low coefficient of expansion, good bearing properties with babbitt, low magnetic transformation temperature, and its galvanic neutrality when coupled with bronze and cast Monel.

Commercially it is available in the "as worked" condition and in the heat-treated state as cold-drawn rods, cold-rolled rods, hot-rolled or forged bars, cold-rolled strip and cold-drawn wire. Tables I, II, and III show the relation of the mechanical properties and the Brinell hardness for the common mill forms.

As a material for springs "K" Monel can be worked from a soft rod or formed hot and the spring temper developed by heat-treatment to obtain a proportional limit of 80,000 lb. per sq. in. and a tensile strength of 140,000 lb. per sq. in. By combining 65 per cent cold-drawing with heat-treatment, a breaking strength of 160,0000 to 180,000 lb. per sq. in. can be obtained in some sizes.

The data given in Table VI relative to the endurance limit of "K" Monel were recorded on a rotating cantilever type fatigue testing machine, operating in air at normal temperatures.

In the soft condition "K" Monel has the same impact value as regular hot-rolled Monel. Impact values shown in Table VII indicate the decrease in impact resistance values with increasing hardness.

Under ordinary working conditions "K" Monel is non-magnetic and remains so down to 79 deg. C. below zero. Measurements at field strengths from 10 to 300 gilberts per cm. have shown the permeability to be 1.0 at room temperatures. This property is desired in alloys used in the construction of directional instruments used in navigation.

After it has been heat-treated to produce maximum hardness "K" Monel will not show appreciable change in properties if again heated to, or held at, any temperature up to that at which the original heat-treatment was carried out. If the rate of cooling in the original heat-treatment was rapid between 1050 and 800 deg. F., there may be a small increase of properties. When subsequently heated above 1050 deg. F. and either quenched or slowly cooled a decrease in properties, as shown in Fig. 3, will take place.

The changes in the physical properties of "K" Monel under continued heating at 800 deg. F. after a 16 hour heat-treatment are shown in Table VIII. After the first month the change caused by slow aging is negligible.

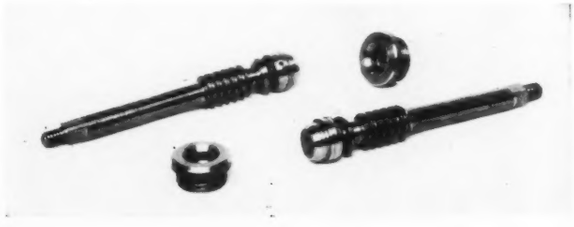
In hardnesses up to 300 Brinell "K" Monel can be machined at practical production rates with no unusual difficulty.

Oxyacetylene and metallic arc welding are both used with "K" Monel. Gas welds have a hardness of about zero Rockwell C, but can be raised to 20 to 23 Rockwell C by heat-treating. Silver solders are available for brazing.

Chemical stability of "K" Monel does not rely upon the maintenance of a protective film. The general corrosion resistance of "K" Monel in all forms and hardnesses is comparable to that of Monel in a wide variety of media, including mineral and organic acids, alkalis, salts, potable and industrial waters, food products, organic compounds and atmospheric oxidation at normal and elevated temperatures.

[*The Development and Research Department of The International Nickel Company are about to issue a new bulletin containing all of the curves and tables given here with additional data on machining practice. Free copies of this forthcoming bulletin can be obtained by writing the editor.*]

Valve disks and seat rings machined from "K" Monel bar stock



Ball bearing assemblies with balls, races and cones of "K" Monel

COMPOSITION

Nickel	66.00	Manganese	0.4
Copper	29.00	Carbon	0.15
Aluminum	2.75	Silicon	0.25
Iron	0.9	Sulphur	0.005

PHYSICAL CONSTANTS

Density	8.60
Weight, lb. per cu. in.	0.31
Melting Point, deg. F.	2400—2460
Melting Point, deg. C.	1315—1350
Specific Heat (20–400 deg. C.)	0.127
Thermal Expansion (average coefficients):	
(25–100 deg. C.)	0.000014
(25–300 deg. C.)	0.000015
(25–600 deg. C.)	0.000016
Heat Conductivity (0–100 deg. C.), c.g.s.	0.043
Electrical Resistivity (at 23 deg. C.):	
Hot Rolled or Forged and Quenched—microhm cm	62.8
Hot Rolled or Forged and Quenched—Ohm per mil-foot	378.
Heat Treated—microhm cm	62.0
Heat Treated—Ohm per mil-foot	373.
Temp. Coef. of Elec. Resist. per deg. C. (23–100 deg. C.)	0.00019
Magnetic Transformation Temp. deg. C.	Below.—79

PROPERTIES

Modulus of Elasticity in Tension	26,000,000
Modulus of Elasticity in Torsion	9,500,000

TABLE I.

Mechanical Properties—Rods, Bars and Forgings

Condition	Tensile Strength lb./sq. in.	Yield Strength 0.2% Set lb./sq. in. Minimum	Proof Stress lb./sq. in. Minimum	% Elong. in 2 in. Min.	Approximate Hardness	
					Brinell 3000 kg.	Rockwell C Scale
Hot Rolled or Forged	110,000 max.	.....	.....	30	190 max.	16 max.
Hot Rolled or Forged—Heat Treated	140,000 min.	100,000	80,000	20	265 min.	27 min.
Cold Drawn Rods, over ⅜ in. up to but not including 1 in.	135,000 max.	.....	.....	13	260 max.	26 max.
Cold Drawn Rods, 1 in. to 3 in. inclusive	125,000 max.	.....	.....	13	240 max.	24 max.
Cold Drawn Rods, ⅜ in. to 1 in. as above—Heat Treated	145,000 min.	110,000	90,000	15	290 min.	31 min.
Cold Drawn Rods, 1 in. to 3 in. as above—Heat Treated	140,000 min.	100,000	80,000	17	265 min.	27 min.

Notes: Yield Strength by Set Method A. S. T. M. Methods of Tension Testing Metallic Materials, A. S. T. M. Designation E–8–33, Paragraph 26–2(a). Same in U. S. Navy Genl. Specs. for Inspec. of Material, Appendix II, Paragraph 10(g)2.

Proof Stress is permanent elongation on release of load of 0.0001 inch per inch of gage length, U. S. Navy Spec. as above, paragraph 10f.

TABLE II.

Mechanical Properties—Strip

Condition (d)	Tensile Strength lb./sq. in.	Yield Strength (c) lb./sq. in.	Elong. % in 2 in.	Approx. Hardness	
				Sclero-scope	Rockwell C Scale
Cold Rolled, Soft	105,000 max.		25.0 min.	23 max.	8 max.
Cold Rolled, Soft—Heat Treated	130,000 min.	90,000 min.	10.0 min.	35 min.	20 min.
Cold Rolled, Half Hard (a)	125,000 min.	85,000 min.	5.0 min.	30 min.	15 min.
Cold Rolled, Half Hard—Heated Treated	150,000 min.	100,000 min.	3.0 min.	45 min.	28 min.
Cold Rolled, Full Hard (b)	145,000 min.	105,000 min.	3.0 min.	40 min.	25 min.
Cold Rolled, Full Hard—Heat Treated	170,000 min.	125,000 min.	2.0 min.	50 min.	33 min.

(a)—approx. 20% reduction.
(b)—approx. 50% reduction.
(c)—by drop of beam or dividers.
(d)—no tensile requirements under 0.020 in. thick; substitute Shore scleroscope hardness.

TABLE III.

Mechanical Properties of Cold Drawn Wire (up to and including ⅜ in. diam.)

Condition	Tensile Strength lb./sq. in.	Elongation % in 2 in. Minimum
Cold Drawn	155,000 max.	4.
Cold Drawn, Heat Treated	165,000 min.	5.

All wire shall withstand being bent through 180 deg. around a rod of the same diameter as the wire without cracking.

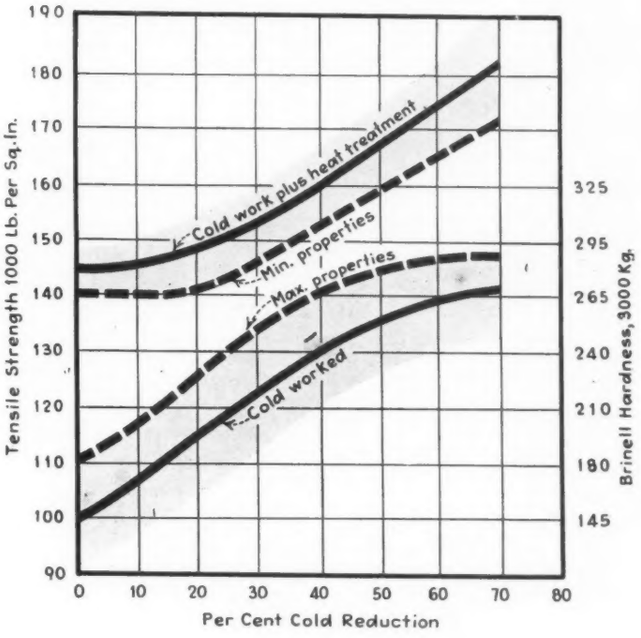


Fig. 1—Effect of cold-work and heat-treatment. Heavy full lines indicate average properties. Stippled areas cover range of commercial products. Dash-lines are upper limit for cold-worked and lower limit for heat-treated products respectively

TABLE IV.

Double Shear Strength

Alloy	Tension		Double Shear	
	Tensile Strength lb./sq. in.	Elongation % in 2 in.	Maximum Strength lb./sq. in.	Deflection at Max. Strength in in.
"K" Monel	97,500	49.0	65,300	0.08
"K" Monel	155,600	24.0	98,700	0.05
Monel	69,800	50.0	49,200	0.08
Monel	108,000	11.5	65,200	0.03
Nickel	68,000	46.0	52,300	0.09
Nickel	120,500	17.0	75,300	0.05
Inconel	85,000	45.0	60,800	0.08
Inconel	152,000	7.0	82,400	0.03

These double shear strength measurements were made with the cutters set with a very small clearance (0.005 in.). This type of test simulates the service requirements of pins used in shackles or clevises.

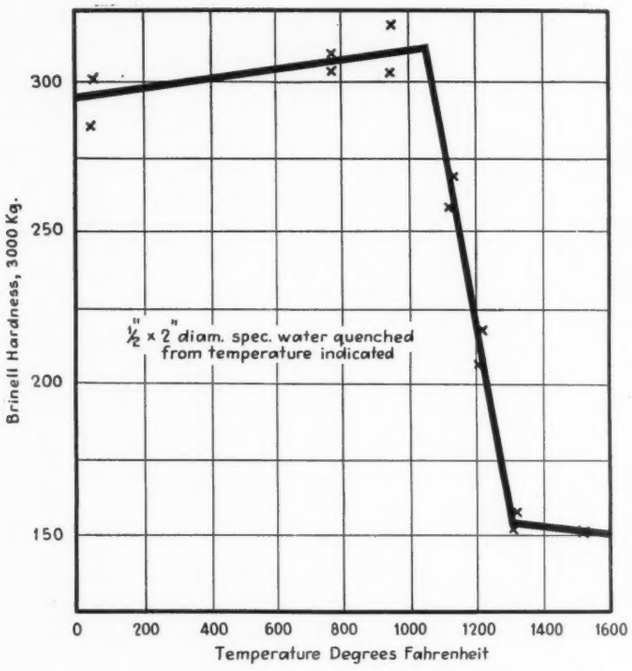


Fig. 2—Graph of observed data showing effect of quenching from temperature on hardness. Partial softening between 1,060 deg. F. and 1,300 deg. F. Complete softening at 1,450 deg. F. Data from P. R. Kosting

TABLE V.
Strength at Elevated Temperatures of Cold Drawn Rod—Heat Treated

Temp. deg. F.	T. S. lb./sq. in.	Y. S. 0.2% Set lb./sq. in.	Y. S. 0.01% Set lb./sq. in	Elong. % in 2 in.	R.A. %
75	165,000	125,000	105,000	21.0	38.9
200	163,000	124,000	104,000	21.0	37.0
400	156,000	118,000	100,000	20.0	35.0
600	147,600	108,600	84,100	19.5	32.8
800	125,000	106,000	81,300	18.5	29.8
1000	124,600	102,800	70,500	9.5	9.8

TABLE VI.
Limiting Stress in Fatigue for Rods

Brinell Hardness Number	Tensile Strength lb./sq. in.	Proof Stress lb./ sq. in.	Million Cycles in Test	Limiting Stress lb./sq. in.
145	90,000	26,000	70	38,000
170	106,000	63,000	20	45,000
285	142,000	101,000	30	50,000
330	158,000	105,000	20	52,000

TABLE VII.
Impact Values

Tensile Strength lb./sq. in.	Standard Izod Test Ft. Lbs.	Tensile Charpy Test* Ft. Lbs.	
		Trans.	Long.
Up to 130,000	100–120	56	81
130–140,000	80–100	—	—
140–160,000	40– 80	44	53

* Tensile impact test method and specimen as used at Watertown.

TABLE VIII.
Long Time Aging
All Samples from the Same Melt
HOT ROLLED ROD

Treatment	Tensile Strength lb. /sq. in.	Yield Strength 0.2 % Set lb./sq. in.	Elong. % in 2 in.	Reduction in Area %	Izod Impact Ft. lbs.	Brinell Hardness
As Hot Rolled	99,500	42,000	46.0	59.9	84	181
16 hrs. at 1080°F.	148,500	90,450	29.0	41.6	48	304
16 hrs. at 1080° F. followed by						
1 month at 800° F.	161,250	108,500	26.5	38.2	27	336
2 months at 800° F.	163,750	111,000	27.0	41.3	23	335
4 months at 800° F.	161,500	107,750	27.0	42.2	24	333
8 months at 800° F.	163,000	112,000	25.0	37.2	27	332

SUMMARY OF HEAT TREATMENT

Soft "K" Monel (less than 180 Brinell) is obtained by hot rolling or forging followed by water quenching from 1450 deg. F.

Hard "K" Monel (265 to 315 Brinell) is obtained as follows:

(a) For hot rolled for forged forms (which have been softened by quenching):

Heat to 1200 to 1250 deg. F. for ½ to 1 hour followed by controlled slow cooling (25 deg. per hour maximum) down to 800-900 deg. F. Cool as desired from 800 deg. F. to room temperature.

(b) For forms moderately cold worked (20 to 30% reduction of cross section):

Heat to 1080-1100 deg. F. for 10 to 16 hours and cool in furnace or heat to 1080 to 1100 deg. F. for 6 hours followed by controlled slow cooling as in (a).

(c) For severely cold worked products (50% or more cold reduction):

Heat to 980 to 1000 deg. F. for 6 hours followed by controlled slow cooling as in (a).

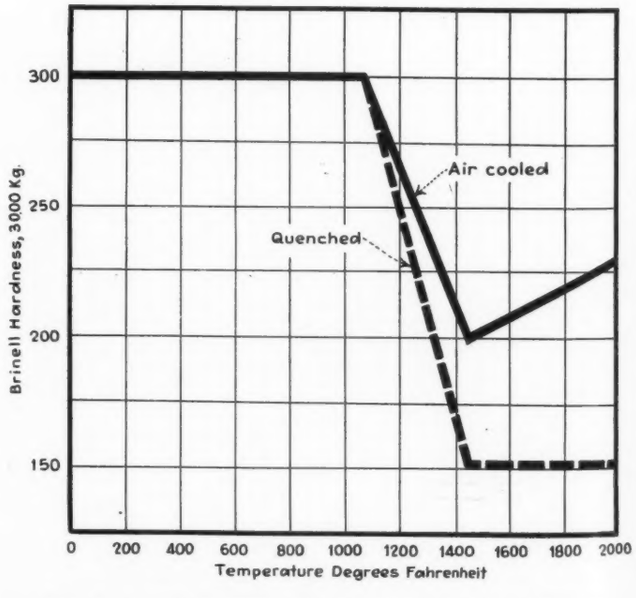


Fig. 3—Partial softening of "K" Monel by air-cooling or quenching from temperature

OVERLOAD RELAYS

Types and Their Characteristics

C. G. ARMSTRONG
Control Engineer, Westinghouse Electric & Mfg. Company

A concise explanation of the operation of motor-protection relays, setting forth the desirable features and limitations of the more commonly used types

AN ELECTRIC motor, willing but woefully unintelligent, will tackle any job without reserve, and quietly but persistently struggle to self-destruction unless called off. Often the operator, intent upon the primary job at hand, may be unaware until too late that the motor is in distress. Or it may be necessary that the motor be depended upon to operate without supervision. Therefore the overload protective relay, "the motor watchman," is appointed as a conservator, to add that spark of intelligent supervision which makes the motor a perfect servant.

Overload relays are of several types, utilizing various physical laws and forms of energy for their operation. They may be magnetic or thermal. Reset may be manual, automatic, or electric. Thermal relays may depend for operation upon thermal expansion, bimetallic warping, or the melting of fusible alloys. Trip characteristics may be inverse time, instantaneous or inverse time up to a certain value above which the trip is instantaneous.

In thermal relays the active elements may be heated by direct action of the current, by thermal conduction or radiation from an auxiliary heater, or by transformer action. The calibration of the relays may be adjustable in steps by changing trip elements, heaters, or coils, and may or may not be provided with means for vernier adjustment between steps. The calibration may be sensitive or insensitive to changes in ambient temperature.

Certain advantages and disadvantages are inherent in the different types, varying with the particular control application and being magnified or minimized by details in design.

Types of Overload Relays

A typical magnetic relay consists essentially of a coil, through which the motor current passes, and an iron plunger to which is attached a piston operating in an oil-filled cylinder. Such a device, shown in Fig. 1, is made up of two relay elements in a common magnet frame, operating a common contact arm. When the motor current exceeds a particular value, the plunger rises against the retarding action of the piston over a portion of its stroke and then is suddenly released.

During this rapid portion of the stroke it separates the electric contacts, thereby opening the coil circuit of the controlling contactor. The time delay is dependent upon the size of an adjustable orifice in the piston, upon the viscosity of the oil, and bears an inverse relation to the magnitude of the overload current. On reset, the oil is bypassed around the piston as the plunger returns to its original position, so that there is practically no time delay.

An overload relay which combines magnetic and thermal action is shown in Fig. 2. This direct-current relay depends for its action upon the fact that Invar, a nickel steel alloy, suddenly loses its magnetic properties when heated to a certain temperature. A steel armature rests upon an Invar strip carrying the motor current. The current also passes through a coil, the field of which is divided in such manner that it acts either to hold the armature down on the Invar, or to lift the armature when the Invar loses its magnetism, thereby causing it to separate the control contacts.

Delay is dependent upon the time required to heat the Invar up to a certain temperature but, when the field exceeds a particular value, trip becomes instantaneous as the result of magnetic saturation in the portion of the field acting through the Invar. This is a feature which is particularly desirable with

Fig. 1—Magnetic overload relay combining two relay elements in a common magnet frame which operate a common contact arm. It has inverse time delay and quick opening of the contacts

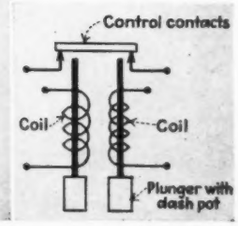
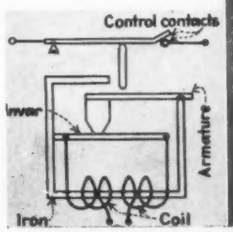
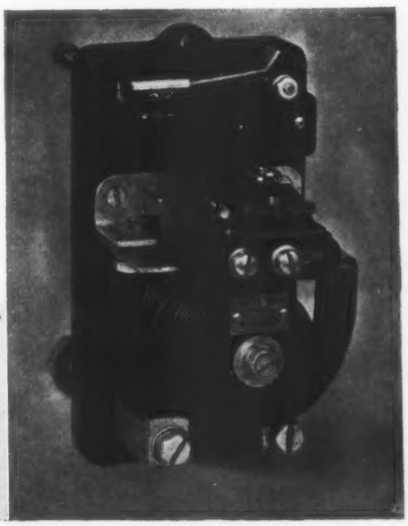
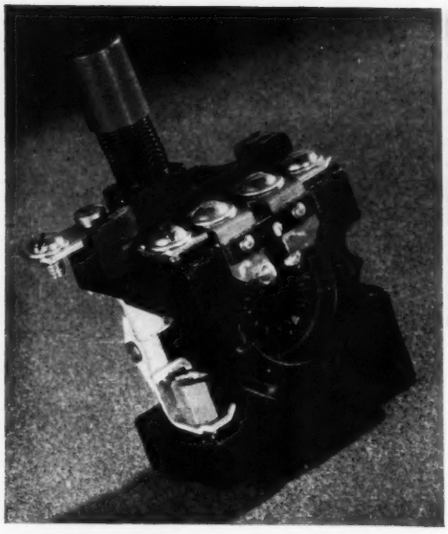


Fig. 2 — Combination thermal-magnetic relay using Invar, which loses its magnetic properties at 200 deg. C., to obtain the time-delay feature







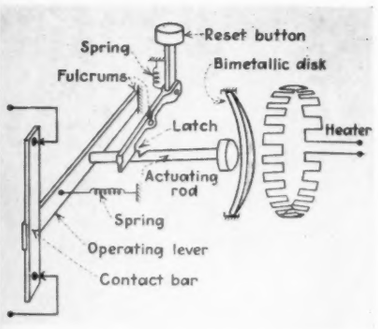


Fig. 4—In this thermal overload relay a bimetallic disk suddenly reverses its concavity when it is heated to a given temperature, thus acting to separate the contacts and causing a reset rod to latch the relay contacts in open position until manually reset

direct-current motors that are driving loads which may jam.

In Fig. 3 is shown a thermal relay using a bimetallic strip. Bimetal consists of two dissimilar metal strips rolled and welded together over their adjoining surfaces, the two metals having considerably different coefficients of thermal expansion. In the relay, the bimetal strip is partially enclosed by a heater carrying the motor current, and the unequal expansion of the two metals causes the bimetal to warp, carrying a latch to the position at which it trips and deflects a micarta bar, suddenly opening the control contacts.

A relay using a bimetallic disk is shown in Fig. 4. The disk is cupped. and when heated the unequal expansion of the two metals of which it is composed cause it to suddenly reverse its concavity at some definite temperature. When cooled, it suddenly snaps back to its original shape. The disk is heated by a heater carrying motor current, the snap action of the disk being utilized to operate a set of contacts. A reset rod is arranged to latch open the contacts upon tripping and prevent them from resetting until after the rod is depressed. Automatic reset is obtained by omitting the rod.

Motors are protected by one of these bimetallic disks and a set of contacts all built into a small unit arranged for mounting in the motor frame or directly on the motor windings. The disk is heated by the motor and is set to trip when the temperature becomes excessive. The contacts may be connected to open the motor-control contactor or to operate an alarm or signal in case it is inadvisable to shut down the motor immediately. It automatically resets when the motor has cooled to a safe temperature.

Fusible-Alloy Type

Fusible-alloy thermal relays consist of a latching mechanism imbedded in a low-melting-temperature alloy which is heated by a resistance element through which the motor current passes. Melting of the alloy releases the latch and permits the contacts to trip by action of a spring. Calibration is obtained by changing heater elements or changing the relative position of the heaters.

For accurate trip, and to avoid trouble in resetting during plasticity, an eutectic alloy having a sharp melting and freezing point must be used. It is important that the alloy be of such nature that the alloying elements will not tend to segregate. Moreover, the alloy should neither change its melting temperature as a result of alloying with the material of the enclosure nor be affected by gradual oxidation over a long period of time.

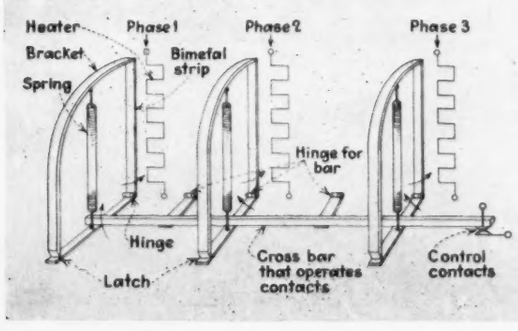
Operating Characteristics

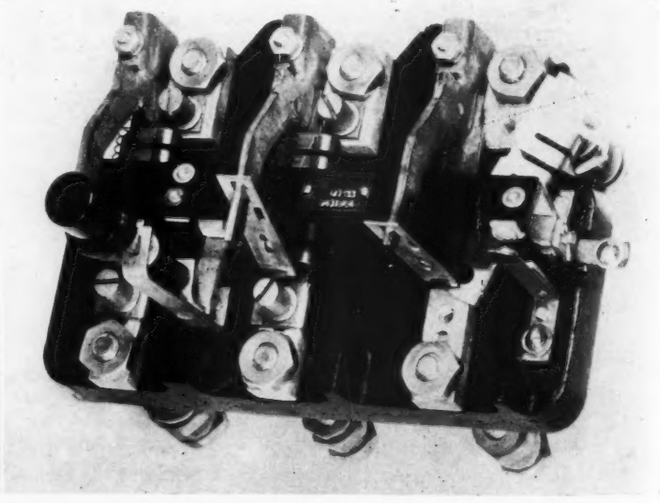
Operating characteristics of various relays are compared in Fig. 5. It is in general desirable that the tripping time of the relay on overload currents follow the thermal characteristics of the motor, permitting operation to the limit of safe motor temperatures under various conditions of short time overload.

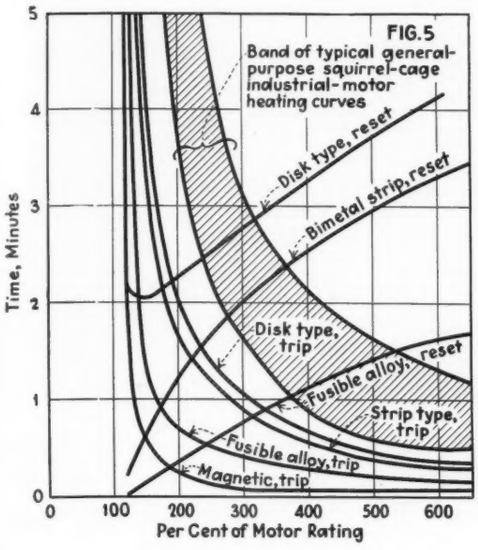
It will be noted that the tripping time of the magnetic relay is short relative to that of thermal relays of comparable size. To assure reliability, it is not desirable to set this type of relay for too slow piston travel. The ripping times of thermal overload relays vary with the condition of service just prior to the time at which the overload occurs. The curves shown in Fig. 5 indicate the tripping time from a cold start. If the overload occurs after the motor has been carrying full-load motor current the tripping time is less.

It is difficult to provide adequate protection to a motor under conditions of heavy, intermittently repeated overloads. In a magnetic relay, the reset time is short, and the trip time is independent of previous conditions of service. It is evident therefore that, even though the trip time of the relay is short, the motor may be overheated by rapidly repeated

Fig. 3—Thermal overload relay with right-hand heater partially removed to show bimetallic strip which moves the spring-actuated trip element to a position where it suddenly trips and operates the contacts







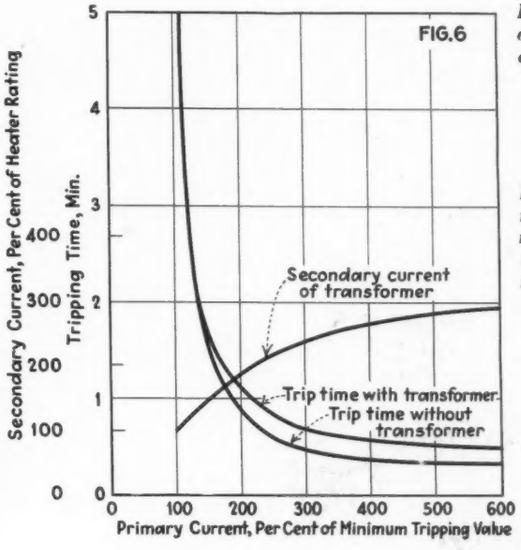


Fig. 5—Comparison of operating characteristics of various types of relays

Fig. 6—Curves showing the modification of overload-relay characteristics effected by the use of saturating current transformers

overloads of relatively short duration.

Although thermal relays are better in this respect, internal ventilation of a motor is dependent upon fan action of the rotor, and consequently its rate of heat dissipation is slow when stationary as compared to that when at work, so that for safety the reset time of the overload relay should be long.

This characteristic is obtained with thermal relays of the disk type, because the reset temperature is lower than the tripping temperature. However, many users are willing to sacrifice safety for convenience and demand a short reset time, so that the motor can be immediately put back to work at reduced load.

Reset-Time Factors

After the relay has given notice of overload by tripping, the operator should observe discretion until time sufficient for the motor to cool has elapsed. Relatively short reset time is obtained with bimetallic-strip type relays similar to that illustrated in Fig. 3, in which the reset temperature is almost the same as the tripping temperature. In instances of high overload, the reset time is increased because the time lapse in the transfer of heat from heaters to bimetals permits the heater temperatures to overshoot. This increased reset time is desirable because after high overload the motor requires time for heat to transfer from points of concentration to surfaces of heat dissipation.

Automatic reset is convenient in many applications, particularly where the relay is located in a position remote from the pushbutton station. For such applications an electric interlock operated by the contactor may be connected in parallel with a spring-returned "start" button, so that reset of the relay will not cause the magnetic contactor to reclose until the "start" button has been depressed.

Short-time automatic reset cannot be obtained with a bimetal relay if it is designed with quick-break contacts. Slow-break contacts are objectionable because of probable contact burning and unreliability in breaking the arc. The thermal-magnetic relay of Fig. 2 is able to combine short reset time with quick-break contacts, because the force tripping the contacts is derived from the electric circuit and vanishes after the relay trips. Hand reset on this relay is provided by latching the contacts open after trip. Fusible-alloy relays cannot readily be adapted to automatic reset.

In applications in which the motor drives high-inertia loads the starting current may be high and the starting time long. In such cases the tripping time of the standard relay may not be sufficient for the motor to come to speed. The time may be prolonged by interposing saturating-core transformers between the relay and the line or by paralleling the heaters with a saturating inductance.

Prolonging Tripping Time

Performance of this arrangement is indicated in Fig. 6. To assure reliability under conditions of varying ambient temperatures and possible slight changes in relay calibration, it is undesirable to saturate too highly. If extremely long times are necessary, modification of thermal characteristics of the relay, in addition to the use of transformers, may be necessary.

The temperature at which the thermal element is designed to trip has an important bearing upon relay characteristics. High-temperature relays are advantageous for applications where the ambient temperature in which the control equipment is located is high, or widely variable, in relation to the temperature at which the motor operates.

Low-temperature relays are advantageous in usual applications for a number of reasons. The number of watts required to operate the relay is less, resulting in, first, increased efficiency and minimum heating effect upon coils and other apparatus with which it may be inclosed and, second, increased ability of the relay heaters to withstand high overcurrents without burnout. Further, it makes the characteristics of the relay responsive to changes in ambient temperature in the same manner in which the motor capacity changes. Thus, a motor rated at 40 deg.C. will be able to carry an overload of about 17½ per cent in a 25 deg.C. ambient.

Ambient Temperature Effect

A relay with a trip temperature equal to the rated motor-winding temperature will permit the motor to work to full capacity at any ambient temperature. A relay not responsive to change in ambient temperature will overprotect at low ambient temperature and underprotect if the ambient temperature is 40 deg.C. or higher.

A well designed thermal overload relay for alternating-current applications will protect on overloads up to about ten times normal rating. Fuses rated at not over four times the motor rating or instantaneous trip breakers should be used as back-up protection.

Electric reset has been found to be a desirable feature in many applications. This is readily obtainable in relays of the magnetic, or thermal-magnetic type, the electric reset in these devices taking the form of a small shunt-connected electro-magnet to replace the mechanical hand reset latch otherwise used to hold the contacts from resetting.

The new streamlined Egyptian Zipper rail bus

MODERN DESIGN IN

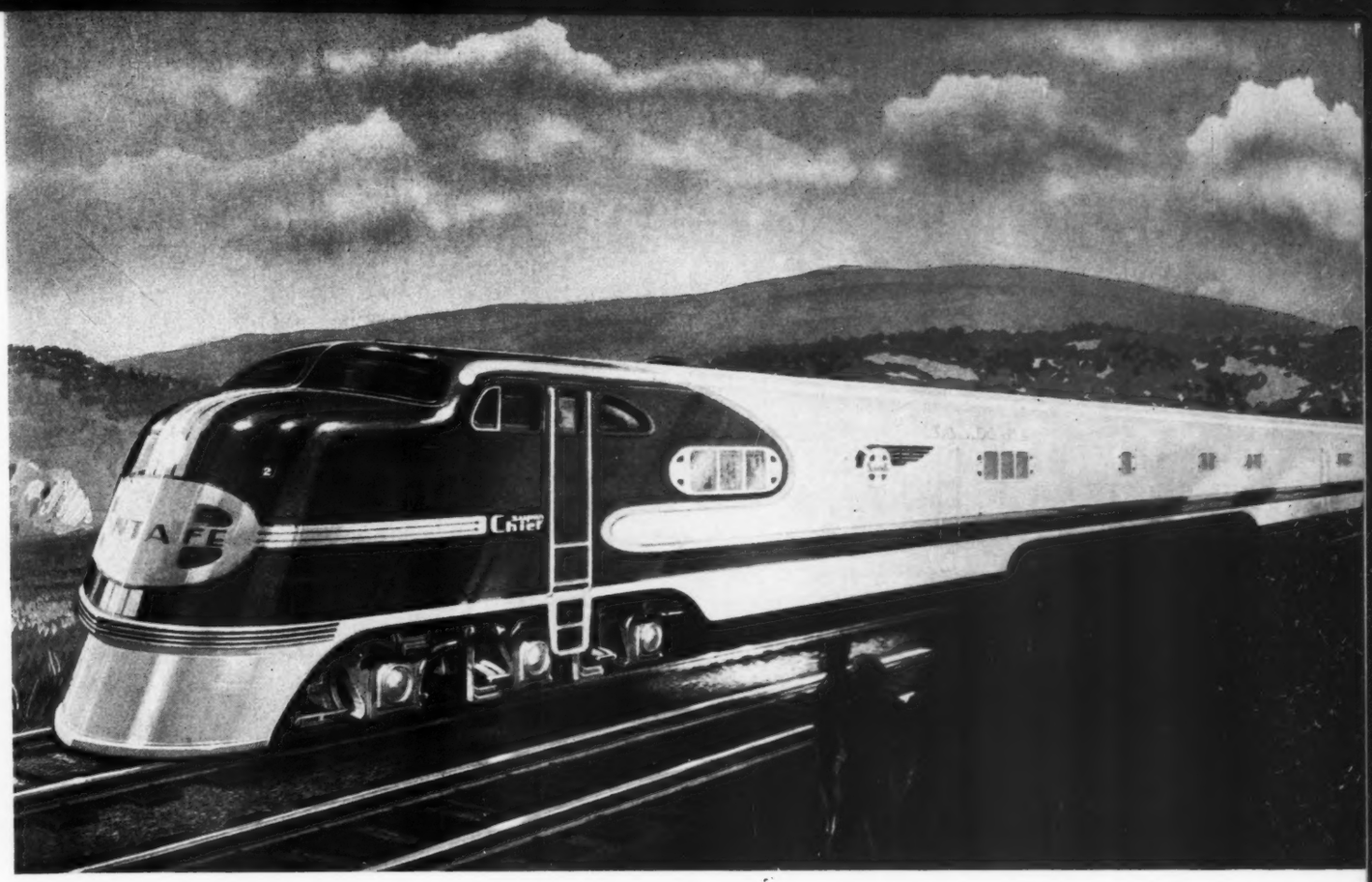
Rail buses are powered by horizontal gas engines operating on gasoline

Operator's cab on the Egyptian Zipper

TWO new rail motor coaches have recently superseded two full-length steam trains on a run of 242 miles on the Chicago and Eastern Illinois Railway. Designed and built by American Car and Foundry Company the cars are each powered by one Hall-Scott six cylinder horizontal engine which develops 200 hp. at 2,000 r.p.m. and operates on gasoline. The engine, the single plate-type clutch and the transmission are mounted to the car underframe on rubber bushings. On the drive axle are two free running spiral bevel gears with jaw-clutch hubs; these gears mesh with and are driven by a common pinion. That part of the axle which is between the bevel gears is splined and carries a sliding-jaw clutch so that either one of the two bevel gears may be locked to the drive axle. The jaw clutch is shifted by levers from the operator's seat. This arrangement permits full speed operation in either direction.

Three windows fitted with shatter-proof plate glass are in the streamlined rounded front. The rear end of the car is sloping and contains windows, it also has doors which permit access to the air conditioning equipment mounted in the rear end.

The basic structural materials used for the cars are aluminum sheathing and steel. High strength materials made it possible to use small sections for load members. The underframe is of steel construction welded and riveted together. Side sills are rolled steel Z-bars and angles. Body framing is steel. The front end of car is equipped with a pilot sheathed outside with sheet steel shaped to blend with the car body structure. Sheathing, skirts and letter panels are aluminum. The arch type roof is covered with copper-bearing steel riveted to the carlines and to the steel side plates. Outside and inside window sash are aluminum. Door locks and hardware in passenger compartments are chrome plated bronze that harmonize with the decorative scheme.



Santa Fe's stainless steel train Super Chief

RAILROAD EQUIPMENT

Streamlined stainless steel train is hauled by diesel-electric locomotive

A nine car train, known as the Santa Fe Super Chief, drawn by a diesel-electric locomotive, is now in regular service on the Chicago-Los Angeles run of 2,225 miles. The cars of the Super Chief were built by Edward G. Budd Manufacturing Company. They are hauled by a 3,600 hp. locomotive constructed by the Electro-Motive Corporation. Two 1,800 hp. units coupled for multiple unit operation controlled from a single station furnish the motive power. Each unit is made up of two 900 hp. at 750 r.p.m. diesel-electric power plants controlled jointly from the locomotive throttle. The engines are of the two-cycle V-type and each has 12 cylinders of 8 in. bore and 10 in. stroke. Connecting rods are drop-forged, the wrist pins have needle-bearings and the pistons are aluminum. The engine crankshafts are of the seven-bearing type.

The main 600 volt d.c. generator has a differential voltage control through a belt-driven exciter and auxiliary generator set. Two motors are geared directly to the driven axles of each truck.

In constructing the cars two types of stainless steel were used. For members intended to give strength to the structure a high-tensile material was employed having a tensile strength of 150,000 lb. per sq.in. Where ductility or finish was important a material having 100,000 lb. per sq.in. tensile strength was used. A truss type of construction with channels for vertical and diagonal members formed the car frames.

To decrease heat transfer between the interior and exterior of the cars the roofs, side walls and end walls were lined and padded with an insulating material. Windows in the passenger sections are double glazed with both frames set in rubber to eliminate the transfer of strains to the glass.

Hydraulic shock absorbers are installed to dampen the lateral movement of the truck bolsters. The coiled truck springs are made of silico-manganese steel; chrome-vanadium steel is used for the elliptic springs.

One of the Super Chief's cars under construction

Question and Comment

Designs for Rotary Swaging

W. L. BOWEN, JR.
The Torrington Company
Torrington, Conn.

Since the success of most fabricated metal parts to a great extent depends upon the designer, it is necessary for him to have a broad knowledge of the various methods of fabricating metal. Unfortunately many designers are not familiar with the wide variety of work which can be produced by the process of rotary swaging, using the modern machines built for this purpose, as explained in the following paragraphs.

Rotary swaging consists, briefly, of reducing a wire, bar, or tube of any regular cross-section to a round cross-section. Lengthwise of the piece, the result may be a taper, a straight cross-section or a point of limited sharpness, as shown in the accompanying sketches, Fig. 1 and 2. These forms are produced by the action of two or four dies striking approximately 2,000 blows a minute as they rotate around the axis of the work while the work is being fed endwise into the swaging machine. Fig. 3 illustrates the action of the dies and shows the principle of their operation.

The process permits rapid production, and ordinary reductions are accomplished at a rate of approximately ¾ in. per sec., while with some jobs, such as the rounding-up of tubing, this rate may run as high as 2 in. per sec. Since the material is merely moved from one shape to another there is no loss or waste; in fact, on solid work the material is elongated, thus showing an actual saving as compared to reducing by turning. Fig. 1*A* and 1*B* illustrate this point. As to finish and tolerances, sections produced by rotary swaging have a surface smoothness comparable to that of a good grinding job and the diameter tolerances are about half that of ordinary screw machine work. Moreover, the process is economical; expert operators are not required and both die and set-up costs are relatively low. As compared with many other machine tools, the cost of the rotary swaging machines themselves is much lower.

In many instances where the diameter is so small as to make turning difficult, wires can be readily reduced by rotary swaging, as indicated by Fig. 1*E*. Furthermore, such a reduction is always accompanied by an increase in the tensile strength and the elastic limit, the amount of this increase depending upon the type of steel being reduced. The same applies to rods or bars of any regular cross-section, square, hexagonal or octagonal.

The reduction of tubing by rotary swaging is subject to a larger variety of possibilities because the inside and outside diameters can generally be produced, if desired, to two different sets of specifications on the same piece. For example, a piece of tubing may be swaged so as to have a straight taper on the outside and a double taper with a step on the inside, or a straight taper could be produced on the outside with a smooth, straight hole on the inside. Fig. 2*B* and 2*C* exemplify these possibilities. The only limiting factor for this type of swaging is that there should be enough material in the cross-section of the tube to produce the final cross-section. Also, the part should be designed so that any reverse tapers on the job are not such as to lock-in the mandrel used to control the inside dimensions of the swaged section. Fig. 4*A* shows a part with reverse tapers locking-in the mandrel.

When tubing is swaged over a mandrel, the hole produced has the finish and accuracy of the mandrel. Welding torch nozzles and similar articles are produced by this method. The taper on the outside of the nozzle and the smooth hole on the inside are formed by the same operation, thus eliminating the need for drilling and reaming the hole.

It should be remembered, however,

Fig. 1—Examples of solid work that can be produced by rotary swaging

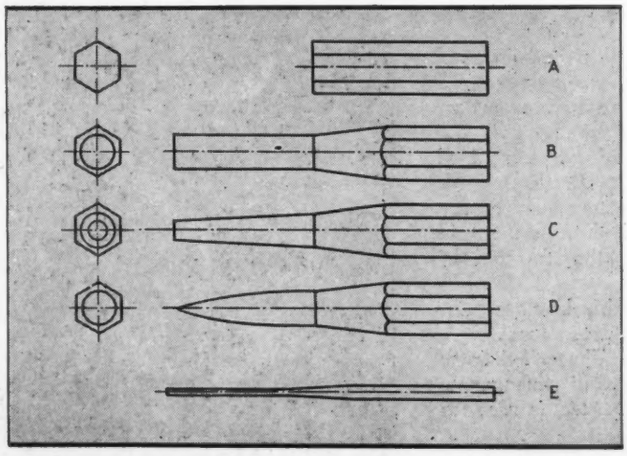
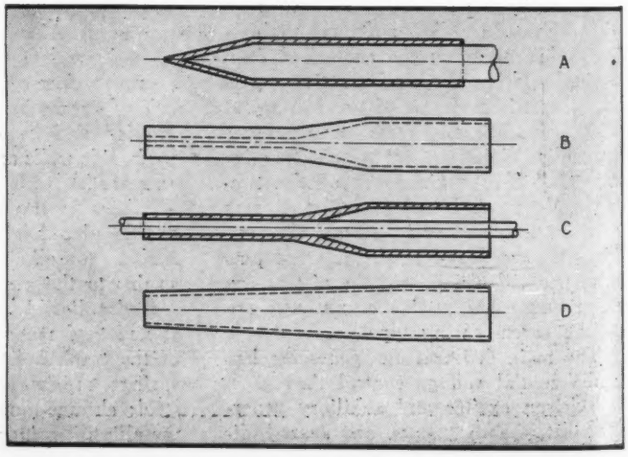


Fig. 2—A few of many tubular parts in which both inside and outside diameters are rotary-swaged



that tubing with excessively thick walls is likely to grip the mandrel, although this can often be remedied by proper lubrication.

Tubing with walls of sufficient thickness can also be swaged so as to close-in on the ends, as shown in Fig. 2*A*. Tubes for hair curling irons, javelin points and similar articles are generally produced in this way.

Very often, tubing can be rounded-up by running it through a rotary-swaging machine. In work of this sort the tubing is only reduced a few thousands of an inch, just enough to round-up the outside diameter, as well as the inside, by the action of the swaging dies.

For ideal rotary-swaging conditions, the included angle of the taper between the original or large diameter and the reduced or small diameter should not be more than about 10 deg. This figure generally applies to low-carbon or mild steel. On copper, brass or lead, this angle may be increased in proportion to the compressive strength of the material. However, on high-carbon steels and alloy steels it is sometimes necessary to use an included angle of taper of less than 10 deg.

A maximum reduction in area of from 34 to 40 per cent, or slightly less, generally gives the best results from the standpoint of production. This can at times be increased in the same manner as the angle of taper; that is, increased approximately in proportion to the compressive strength of the material being swaged. Likewise this reduction of area should be lessened somewhat for the high-carbon and alloy steels.

Where heavy reductions are absolutely necessary, they usually can be accomplished more readily by resorting to two or three successive operations than by attempting to make the entire reduction in one swaging pass. Generally the work is fed into the machine by hand, but where comparatively steep tapers or heavy reductions are required it is not unusual to employ a hand rack-and-pinion feed for the purpose of forcing the work into the die.

When designing for rotary swaging, shape either by turning or by striking with a press.

Since the maximum length of taper that can be produced by a swaging die in one operation is slightly less than the length of the die itself, it can be seen that continuous straight tapers three or four feet long would be expensive to produce by this method because of the large number of swaging operations necessary. The designer can overcome this difficulty by using a step taper, that is, by connecting fairly long sections of the same diameter with tapers that are a little shorter than the die. Fig. 4*D* and 4*E* show how such a step taper can be made to approximate a continuous taper. A properly designed step taper of this nature is often just as suitable as a long, straight, continuous taper and can be produced with considerably fewer swaging operations.

Other examples of the work that can be produced by modern swaging machines could be given but the foregoing are representative enough to show the designer what should or should not be attempted. With these possibilities and limitations in mind, he can better decide which parts in his new designs should be laid out in such a way that they can be advantageously produced by rotary swaging.

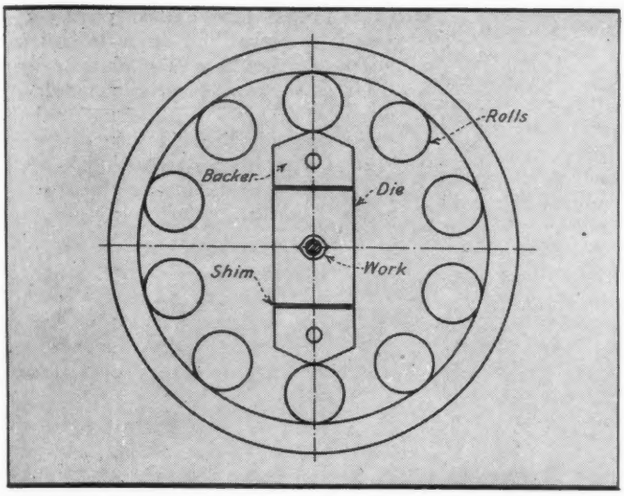


Fig. 3 — Actuated by rolls, the dies in a rotary-swaging machine strike some 2,000 blows per min. as they rotate around work while latter is being fed into machine

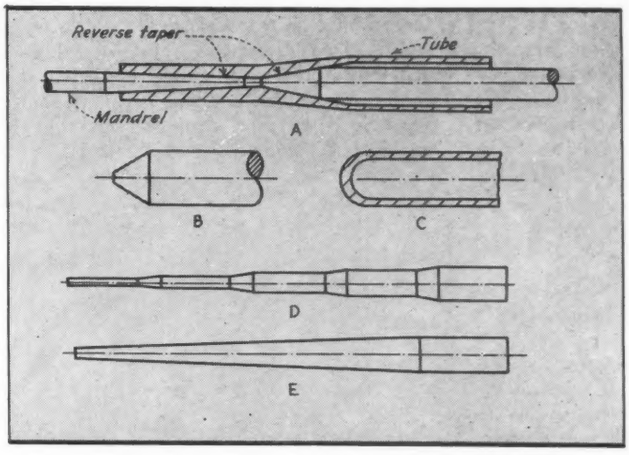


Fig. 4—Several of the things to do or not to do in designing parts to be produced by rotary swaging

blunt or spherical-shaped ends, excessively steep tapers and sharp shoulders should be avoided, Fig. 4*B* and 4*C* being two examples of what not to do. Bullet-shaped ends, however, can be readily produced by rotary swaging but any blunter shape is impossible to produce because then the blows of the dies must be at right angles to the piece. If a comparatively steep taper or sharp shoulder must be had, it is best to design the part so as to permit preliminary reduction by rotary swaging with a comparatively long taper and obtain the final

Finish-Engineering Department

JOHN E. HYLER
Peoria, Ill.

It is now well recognized that a distinctive high-class finish is a powerful factor in the salability of a product. Of two articles identical in design and general quality, the one having a finish that is not all it should be, will remain practically inert on the dealer's floor, while the other with an engineered finish will move rapidly into possession of the ultimate user.

Since one of the greatest problems before the manufacturer is the production of a finish on his goods that will accelerate sales, it follows that he cannot afford to overlook any source of information that will lead him in the right

direction. To this end, the idea of conducting an experimental finishing department is one that has great possibilities. The roughest of initial tests would of course be made on small panels kept for the purpose. Those seeming to give promise would be tried out on a somewhat larger scale, and finally would be tried on an item of the product itself.

A means of supplementary information worthy of serious thought would be the filing, in accordance with some sort of system best adaptable to the form of business served, of data relative to different kinds of finishing materials, equipment and methods, so that it would be possible to draw upon it for ideas when needed. It is evident that at very small cost, ideas of various kinds could be tried out, and there can be no question that while many of them would lead down a blind alley, there would be some valuable methods and finishes discovered in this way which would otherwise never be found. In our opinion, a "finish division" in the engineering department would not be at all out of order. Rather, it is a thing that would have helped keep many currently defunct firms off the rocks.

Stress in Rotating Disk

To the Editor:

In the November, 1935 issue of *Product Engineering*, on page 439, there appeared a chart by Mr. O. E. Brown, giving the stress in a rotating disk.

In checking up on the example presented for a tensile stress of 214,000 pounds per sq.in., I have come to the conclusion that the factor in the stress formula at the top of the page for S, instead of being 10 to the "minus nine" power, should be 10 to the "minus six" power. If you find this is in error, I should appreciate hearing from you.

—Chas. F. Van Hook
Watson Machine Company
Paterson, N. J.

To the Editor:

Mr. Van Hook is correct. The equation should be:

$$S = 71wN^2 \times 10^{-6} \times [(3+m)R^2 + (1-m)r^2]$$

The chart, however, is correct, and gives values which satisfy the above equation rather than the previously published equation.

The mistake possibly came about in the process of changing the units of N from revolutions to thousands of revolutions. In any event, the error was undoubtedly mine, and I regret that it occurred.

—Orley E. Brown
Case School of Applied Science

Factor of Safety in Machinery Design

FRANK A. MICKLE
University of Michigan

There are two definitions of the term, factor of safety, either of which is satisfactory, if properly considered.

1. The factor of safety is the quantity by which the elastic-limit strength is divided to obtain an allowable working stress, thereby insuring proper functioning in all considerations of strength.
2. The factor of safety is the quantity by which the ultimate strength is divided to obtain an allowable working stress, thereby insuring proper functioning in all considerations of strength.

In general design practice, for cases where gradual fracture is not likely to occur, this factor is now more commonly based on the elastic-limit strength of the material.

Many machines are designed and built under codes established by careful study, research, experience and judgment. The designer has no choice or privilege concerning the magnitude or definition of the factor of safety used in these codes.

Although sometimes desirable, in cases not coming under the law, a factor of safety as such is unnecessary.

The frequent expression, "factor of safety or factor of ignorance," is entirely uncalled for. When a factor of safety becomes anything other than what the expression indicates, it is being used by one not competent to design machines or too lazy to make a real factor of safety; then it becomes a factor of laziness.

A blanket factor of safety cannot be fixed for shafting or any other machine part regardless of its use. However, assuming identical construction and application, a factor of safety can be established for every member of a particular size and type of machine.

Following this introduction, it is desirable to give an outline of the terms for consideration in establishing a factor of safety.

In every machine part there are three essential conditions to be considered and avoided: (1) Too great an elastic deformation to allow proper functioning; (2) Loading so as to produce a permanent deformation; and (3) Loading so as to produce gradual fracture.

Although in every case two of these disappear, no one of them can be ignored.

The deflection of a part involves the area of moment of inertia of the cross-section and the modulus of elasticity of the material. The ability to withstand stress does not affect this condition.

Permanent deformation is caused by a stress greater than the elastic strength of the material.

Gradual fracture is due to a repetition of stress at some critical point. The gradual-fracture limit seems to be more nearly a function of the ultimate than the elastic strength of the material. At present the available information indicates that this limit is about fifty per cent of the ultimate strength.

The following outline directs attention to the conditions influencing dimensions of the member:

1. The magnitude of the power at normal working speed.
2. The maximum possible power supply, corresponding speed, and probably frequency of this condition.
3. The care exercised by the operator.
4. The possibility of suddenly applied loads which would stall the motive power; also the distribution of such loads throughout the machine.
5. The number of reversals or repetitions of stress and whether they approach the gradual-fracture limit of the materials used.
6. The possibility of flaws and lack of uniformity of strength of the materials used.

After the analysis of the preceding items, the designer should:

1. Fix the maximum allowable stress, in accordance with item No. 6 as given above.
2. Determine the gradual-fracture limit of the materials.
3. Determine the maximum elastic deformation that will permit proper functioning of the machine.
4. Design the machine parts so that the maximum load will not produce a stress greater than the maximum allowable.
5. Design the machine parts so that the load will not produce an elastic deformation greater than the maximum already fixed.
6. Design the various parts for a stress not greater than the gradual-fracture limit. This requires the use of the maximum load that occurs frequently, causing the safe number of repetitions of stress to be exceeded.
7. Take care to eliminate as far as practicable changes in cross-section that will cause concentration of stresses.

This analysis has not used a factor

of safety. If desirable, the factor of safety, for identical construction, materials and use of parts may be established, as follows:

$$F_E = \frac{W \times S_E}{W_1 \times p}$$

$$F_U = \frac{W \times S_U}{W_1 \times p}$$

F_E = Factor of safety for design, based on the elastic limit

F_U = Factor of safety for design, based on the ultimate strength

W = Design load

W_1 = Normal-rating load

S_E = Elastic limit strength of the material

S_U = Ultimate limit strength of the material

p = Maximum safe stress for a static load, due allowance having been made for variations in S_E

This entire subject is one on which the writer has for some time been attempting to congeal his ideas. Perhaps readers of *P.E.* will offer some constructive discussion.

Length of Tubes for Bends of Various Radii

To the Editor.

In the January 1936 issue of *Product Engineering* you published a table "Lengths of Material For 90 deg. Bends" covering flat metal. Kindly let us know at your earliest convenience if this table applies to round metal, pipe and tubing. If not, can you supply a suitable table covering say ¼ to 1 in. diam. by sixteenths and 1/16 in. to 6 in. radius by sixteenths? If you cannot furnish such a table perhaps you can furnish necessary formulae to aid in the making of one.

—R.A.L.
Chicago, Ill.

[*Editor's Note:* The table does not apply to tubing or round bars. We have been informed by the engineering department of one of the leading tube manufacturers that it is not practical to present either tables or formulae that will give the length of tubing required for various radii bends with a reasonable degree of accuracy. This is because of variables that are always present and are indeterminate. These include the carbon content of the steel, the hardness of the steel, the temperature of the steel at the time of fabrication, the condition of the dies and bending tools, and the method of bending. We are informed that Steel & Tubes, Inc., of Cleveland, Ohio, have available a handbook "Welded Steel Tubing" which gives a few of the simple rules that they adopted to use in the calculation of the length of tubing required.]

Spring-Index Values

To the Editor:

In the second paragraph on page 141 of *P.E.* for April, in W. M. Griffith's interesting and informative article on helical spring design, it is stated that the optimum value of *C*, the spring index, is 9. This is equivalent to 8 if the ratio of pitch diameter of coil to the wire diameter is used.

The writer also passed along this statement for what it was worth in an article in *P.E.*, July 1934, page 279, and was challenged by Frederick Franz, Sept., 1934, page 348. There is no optimum value for the spring index. It is true, that as the index decreases, higher fiber stresses result, and the weight of springs for the same deflection rate and maximum load increases, as shown by the curves on page 348 referred to. It is also true, as Mr. Franz stated, that there is only one index possible, if maximum and minimum spring lengths and loads are given.

—Carl P. Nachod
Louisville, Ky.

To the Editor:

The spring index of 9 included in the writer's recent article was adopted merely for the purpose of providing a starting point for the designer. In other words, a good many men in our engineering department consistently designed springs with small indexes, with the result that it was necessary to employ high stresses. To overcome this tendency and to accomplish some consistency and standardization, it was thought advisable to attempt to provide space, in a new design, for a spring with an index of about 9. Accordingly, springs were originally designed on this basis, and the procedure assured sufficient space to accommodate a spring with moderate stresses under any circumstance.

On the other hand, please note particularly that our records indicate a constant freedom from difficulties where the index is close to 9. This has been true even when the stresses in different springs were approximately the same. However, as was pointed out by Mr. Nachod and Mr. Franz, it is mainly a question of stress although, even on this basis, it is our experience that springs with indexes below 9 frequently fail.

With further reference to this matter, it might be well to mention that the original index of 9 was adopted before the Wahl correction factor was used in our spring formula. On this basis, there was justification in using an index of 9, since this value corresponds with the point on the Wahl curve where the slope starts upward at a rapid rate.

In some respects this is rather an old story but, at the same time, we feel Mr. Nachod must also agree that springs with small indexes are dangerous.

—W. M. Griffith
Oakland, Calif.

Erratum

To the Editor:

In the article which appeared in your June issue under the title "Gear-Bore Proportions," reviewing University of Illinois Engineering Experiment Station Bulletin No. 288, there is an error in the equation given for maximum bore. The equation should read:

$$d = D(0.50 + 0.0344\sqrt{T - 12})$$

It will be noted that the coefficient of the radical is 0.0344 as given above, instead of 0.344 as previously published.

—Paul H. Black
University of Illinois

Can You Work This One?

H. E. SMITH
Newark, N. J.

This Month's Problem—

Larger Income

Shortly after being graduated from an engineering college last month, two young men were employed by a rapidly expanding industrial concern. Each was given the same starting salary of $1,000 a year. However, under Jones' contract, he is to be given an increase of $200 every year; whereas Brown's agreement calls for a raise of $50 every six months. Which will have the larger income?

Solution to Last Month's Problem—

The Commuter

Since the chauffeur arrived home thirty minutes earlier than usual, he saved that much time on the round trip or fifteen minutes each way. He therefore must have met the executive fifteen minutes before the usual time. Since the executive was at the station sixty minutes early but met the chauffeur only fifteen minutes early, he must have walked for forty-five minutes.

PNEUMATIC CONTROL

Diagrammatic illustrations showing ways of connecting valves to single acting, double acting, and interlocking cylinders with controlling apparatus

FIG. 1.—When the control valve of a pneumatically operated mechanism is at a relatively great distance from the controlled apparatus the time required for air to travel from one to the other may be relatively long. To shorten the time element a relay valve located close to the apparatus is sometimes used. Valves of this type are also used when it is impractical to use a pipe large enough to pass the required volume of air from one apparatus to the other. When air pressure is admitted at *A* the diaphragm *B* is depressed and the upper valve is seated which closes the exhaust port, simultaneously the lower valve is opened admitting air from the feed line to the controlled apparatus.

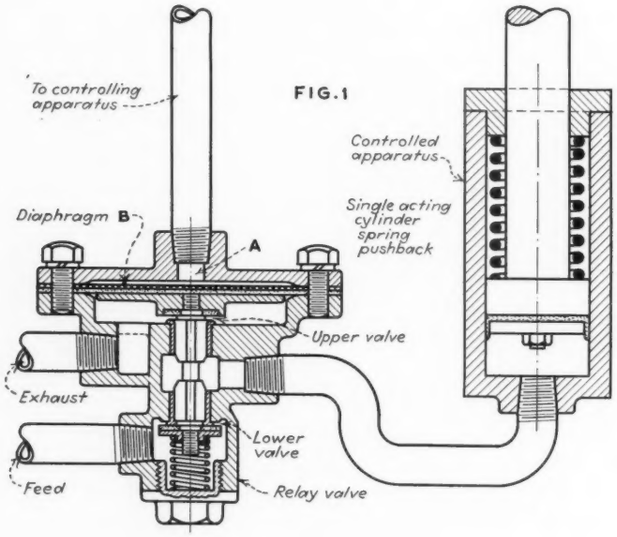
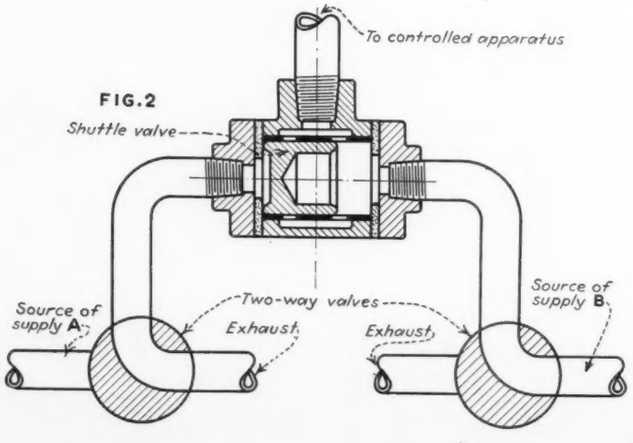


FIG. 2—Operating a piece of apparatus from one or the other of two sources, using a shuttle valve to prevent air pressure from one source of supply to continue on to the other source of supply. When the apparatus is operated from the source of supply *B* air pressure forces the valve to the position shown in the illustration, which will seal the port leading to the other source of supply and permits air under pressure to flow through the port in body to the apparatus. When operated at source *A* the shuttle is forced to the right which opens the left side port.



FIGS. 3 AND 4—Controlling a double acting cylinder with a three-way valve and an auxiliary valve. Fig. 3 shows position of valve when cylinder is pulling. Fig. 4 shows valve position when main cylinder is pushing. Two single acting opposed cylinders may be used in place of the double acting cylinder.

FIG. 5—Interlocking system used on buses to prevent the driver from starting before exit doors are closed. When the exit doors open, a circuit which energizes the magnet valve is automatically completed by the switch mounted on the door engine. When energized, the magnet armature lever moves downward and depresses the push-rod *B* to a seat in the upper valve simultaneously unseating the lower valve which permits air pressure to flow to the interlock cylinders, moving the interlock pistons outwards. The interlock cylinder, which is connected to the brake valve, holds the brake valve in the "brakes applied" position regardless of the position of the driver's brake pedal, and the interlock cylinder connected to the accelerator pedal locks the pedal upward in the engine idling position. When the exit doors close, the magnet valve is automatically de-energized and the spring seats the lower valve and lifts the push-rod allowing the interlock cylinders to exhaust and the springs within the cylinders return the pistons to their original positions, thereby releasing the brake and the accelerator pedal.

CIRCUITS

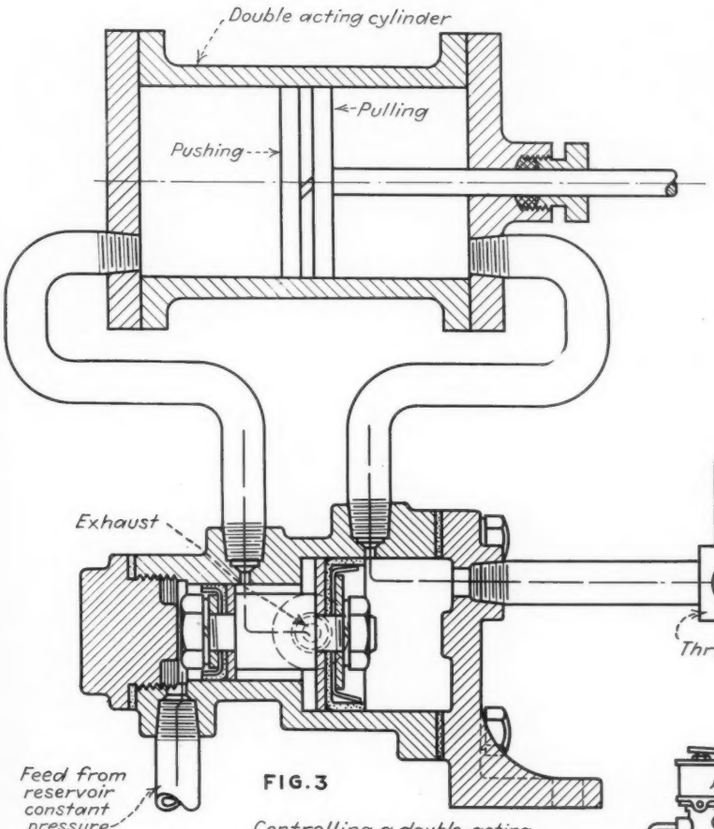


FIG. 3

Controlling a double-acting cylinder with an auxiliary valve and a three-way valve in pulling position

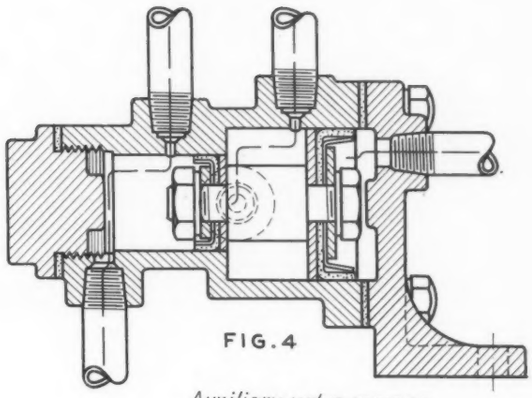


FIG. 4

Auxiliary valve same as in Fig. 3 except this is in position for pushing

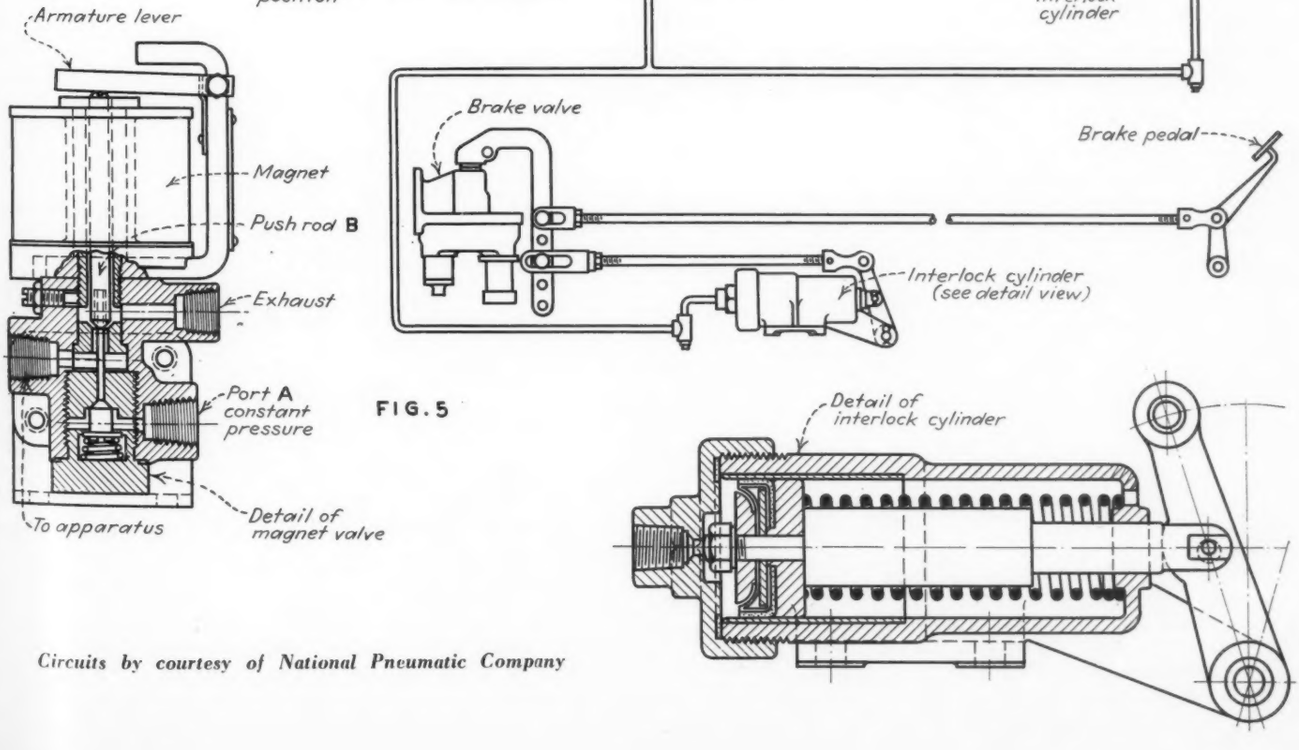


FIG. 5

Circuits by courtesy of National Pneumatic Company

News

Five Million Volt Atom Smasher Started

IN AN ADDRESS before the Edison Electric Institute in the Palmer House, Chicago, on June 7, Dr. L. W. Chubb, Director of Westinghouse Research Laboratory announced that construction of the world's largest unit for "atom smashing" is now being constructed at the Westinghouse Electric & Manufacturing Company's research headquarters in Pittsburgh, Pa. This new research structure will consist of a huge pear-shaped tank, 30 ft. in diameter and 47 ft. high, housing an electro-static direct current generator and other required parts, including a 40 ft. vacuum tube through which particles will be shot in the bombarding of various types of targets. The completed structure, including a two-story building, will be 65 ft. high or about as tall as a 6-story building.

Voltage generated in the "atom-smasher" will range to 5,000,000 and beyond, such high voltages being capable of accelerating particles of matter shot through the vacuum tube to a velocity up to 100,000,000 mi. per hr. On their way to bombard targets at the end of the tube, the particles will be counted, measured and identified by special instruments developed for this purpose. The particles will leap from the end of the vacuum tube through windows of thin metal and strike targets with velocity great enough to penetrate the nuclei of the atoms and thereby produce new substances.

"Physicists today," stated Dr. Chubb, "are still learning about processes, energies and sequences of operations, which will give nuclear reactions and transmutations of one element into another. By constant experimenting they will learn how to duplicate nature's work, how to change elements and how to create new products and processes. Though we do not know where our present work will lead, or exactly what results we shall gain, we know that in this new field are hidden golden nuggets of scientific opportunity."

It is stated that the decision by Westinghouse to embark in the field of atomic disintegration is the first time that an approach to the problem has been made by an industrial concern with such facilities for financing, equipping and engineering work. Prior investigations have been conducted almost solely by college laboratories and small institutional groups.

Dr. Chubb also demonstrated the recently developed electro-static air cleaner which removes about 99 per cent of all particles in the air. Most of these particles are submicroscopic in size, for which reason they cannot be caught by any mechanical cleaning process. The new cleaner, which operates similar to the Cottrell process in that electrically charged particles, when passed between charged plates, jump to the plates and cling there, only the pure air floating out from between the plates. The equipment will even clean the air of cigarette smoke and pollen. The device has already been used in hospitals to clean the air of pollen to relieve patients suffering from hay fever, asthma and similar nose and throat irritations.

In closing his address, Dr. Chubb stated, "Today we think of industrial research as being quantity production of organized research, in comparison with the type of scientific research carried on by the independent worker of the past. It is industry's insurance policy of continuing progress. The research work of a large company, such as Westinghouse, is carried on by 'teamwork'—by a corps of trained engineers working in several branches of science."

Strain Gages Developed For Use Under Impact

ONE OF THE difficulties encountered in trying to apply existing strain gages to the measurement of strain when the member is subjected to dynamic loads has arisen from deformations within the gage caused by the inertia of the gage itself when subjected to high acceleration. Serious errors may result from these deformations. In the past it has been customary to decrease the mass and increase the rigidity of the gage in order to minimize the deformation and in using the gage, the small resulting error was corrected by means of control experiments.

In a new type of design developed by W. M. Bleakney, the ratio of stiffness to the inertia of the parts of the gage is made so that the deformations will be compensating, the indications of the instrument thus being independent of any acceleration of the gage as a whole.

Using this principle of design, the Massachusetts Institute of Technology and the Sperry Gyroscope Company are collaborating in the development of an electro-magnetic strain pick-up unit for the navy department. This instrument is being developed for the Navy Department and is to be used for recording the strains in airplanes during flight.

Dudley Medal Awarded Swanger, Wohlgemuth

AWARDED annually to the author or authors of the paper presented at the preceding annual meeting which is of outstanding merit and constitutes an original contribution on research in engineering materials, the A.S.T.M. Dudley Medal was awarded on June 30 at the 40th annual meeting of the American Society of Testing Materials to W. H. Swanger, chief of the Section of Mechanical Metallurgy, and assistant chief of the Division of Metallurgy, and G. F. Wohlgemuth, associate metallurgist, both of the National Bureau of Standards, for their winning paper entitled "Failure of Heat-Treated Steel Wire in Cables of the Mt. Hope, R. I., Suspension Bridge."

This paper describes the extensive work undertaken at the National Bureau of Standards to determine the causes of the failure of heat-treated wire which was found to be defective shortly before the completion of the Mt. Hope suspension bridge. Heat-treated wire of the same heat was at the time being used in the Ambassador bridge at Detroit, Mich., and the wire in this bridge was also dismantled. The authors in their paper indicated that the manner in which the failed galvanized wires were placed on the anchor shoes subjected them to a fluctuating load, resulting in a range of elastic bending stresses in the wires at the anchor shoes. The uniformly fine-grained steel of the wire, surrounded by the brittle low strength zinc-iron alloy of the galvanized coating, together with numerous surface imperfections acting as points of stress concentration, resulted in

fatigue fracture originating at the surface of the wires. On the other hand, there was definite evidence, according to the authors, that the fibrous structure of the cold-drawn wire which replaced the original galvanized wire tended to turn aside such cracks, whereas the hard fine-grained structure of the heat-treated wire could not act in this way.

Mr. Swanger, a graduate of Pennsylvania State College, with the degree of B.S. in chemistry in 1917, was in military service from August 1917, to September 1919. He then became associated with the New Jersey Zinc company, in which company he had been employed for a short period prior to entering the army. In January 1921, he became affiliated with the National Bureau of Standards.

Mr. Wohlgemuth was graduated from St. John's College, Annapolis, Md., 1919, with the degree of B.S. He was employed at the U. S. Naval Engineering Experiment Station until May 1930 when he became associate metallurgist at the National Bureau of Standards where he continued his work in the physical and metallurgical properties of metals and investigations of metals failures. He is a captain in the Chemical Warfare Service Reserve in the U. S. Army, and in June 1936, he received his M.S. degree, in course, from the American University of Washington.

S.P.E.E. Design Division Discusses College Courses

AT THE annual meeting of the Society for the Promotion of Engineering Education at Cambridge, Mass., June 28 to July 2, the Machine Design Division, under the chairmanship of Professor Luce of Lehigh University held two sessions, one devoted to the presentation of formal papers and the other to a discussion of various phases of mechanical design and the teaching of machine design.

At the general session, Prof. Earle Buckingham of Massachusetts Institute of Technology presented a paper on gear design wherein he discussed general considerations and the nature of the tooth contact and tooth action in the various types of gears.

Under the title of "The Use of Visual Aid in Teaching Machine Design" Prof. Ward E. Bullock of the University of Cincinnati gave his experiences in the use of diagrams, lantern slides, motion pictures and models as aids to teaching machine design. In conjunction with this paper there was a special exhibit of more than 200 electrically driven models of mechanism which were loaned for the purpose, by the Newark, N. J. Museum, this exhibit being similar to the one at the Museum of Science and Industry in Rockefeller Center, New York.

At a discussion meeting on Monday evening, June 28, under the chairmanship of Prof. J. Harland Billings of Drexel Institute, Prof. John A. Pryor of the University of Pennsylvania presented a paper on "The Contribution of Photo-elasticity to Machine Design" and Dr. C. H. Kent of Pennsylvania State College delivered a paper on "The Place of Welding Construction in Machine Design Curriculum." Prof. John A. Pryor of the University of Pennsylvania presented a paper on "The Contribution of Photo-elasticity To Machine Design" and Prof. C. W. Ham of the University of Illinois a paper on "What Should the Undergraduate Know About Balancing and Vibration." Prof. J. Harland Billings of Drexel Institute of Technology delivered a paper "Instructions on Gages and Precision Measurement."

James H. McGraw, Jr. Elected President of McGraw-Hill Publishing Company

EFFECTIVE June 21, James H. McGraw, Jr. was elected president of the McGraw-Hill Publishing Co. to succeed Malcolm Muir, resigned. Mr. McGraw, Jr. continues as chairman of the board and assumes the additional responsibilities of the office of president.

Blank & Stoller

JAMES H. McGRAW, JR.

Following his graduation from Princeton University in 1915, Mr. McGraw entered the service of the company and for twenty-one years has served actively in various posts connected with its publishing activities. After eight years of service with individual papers and groups of papers, he entered the general management of the company as treasurer in 1923, and became executive vice president in 1932. In 1935 he was elected chairman of the board to succeed James H. McGraw, founder of the company.

In 1932 and 1933, Mr. McGraw served as president of the Associated Business Papers and in addition to his work in his own company he has contributed generously of his time and effort to the advancement of business paper publishing. Thoroughly grounded in the editorial tradition, he has applied himself aggressively to keeping the business paper abreast of what is best in modern publishing practice from the viewpoint of both readers and advertisers.

Tables of Materials Reprinted by Bureau

OUT OF PRINT for a number of years, Circular C101, "Physical Properties of Materials; Strengths and Related Properties of Metals and Certain Other Engineering Materials" will now be reissued by the Bureau of Standards. In the 13 years that have elapsed since the last printing of this circular, a number of important corrections have come to the Bureau's attention. These corrections will be printed in a supplement which will be furnished to those ordering a copy of the circular. Those who already have the circular can purchase the supplement separately. The price of the circular with the supplement is 40 cents, while the supplement alone costs 5 cents. Orders should be sent to the Superintendent of Documents, Government Printing Office, Washington, D. C.

Lenses Molded from Plastics

ACCORDING to a report from Britain a method of producing all kinds of lenses by the use of a new plastic material was demonstrated in London recently. Using a specially designed machine, the lenses are delivered from the machine ready for mounting into cameras or other optical instruments with-

out requiring further finishing operations such as polishing.

By using various compositions of plastics and transparent materials, the lenses are made to suit particular purposes and to possess certain optical properties. For all practical purposes, these molded plastic lenses are unbreakable and weigh only about half as much as glass and have certain optical properties which are claimed to be superior to glass.

New A.S.T.M. Officers

AT THE 40th A.S.T.M. Annual meeting held in New York City, June 28 to July 2, the American Society for Testing Materials announced the newly elected officers and executive-committee members for 1937-1938.

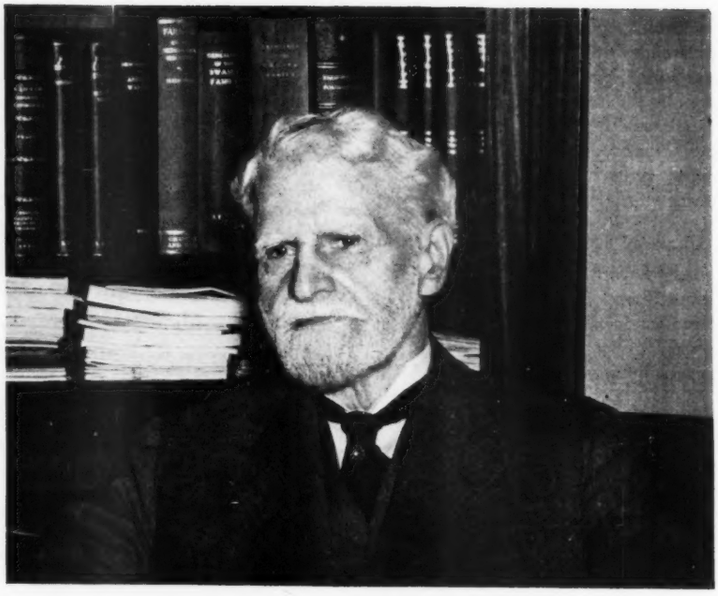
A. E. White, professor of metallurgical engineering and director of the Department of Engineering Research, University of Michigan, was elected president; H. H. Morgan, manager of the Rail and Truck Fastenings Department of the Robert W. Hunt Company was elected vice-president and the following members were elected to serve on the executive committee: P. H. Bates, chief of the Clay and Silicate Products Division of the National Bureau of Standards; H. F. Clemmer, engineer of materials, District of Columbia; G. E. F. Lundell, assistant chief of the Chemistry Division of the National Bureau of Standards; H. C. Mougey, chief chemist and assistant technical director of the Research Laboratories Division of the General Motors Corporation; R. L. Templin, chief engineer of tests, Aluminum Company of America.

Do You Know That—

High-frequency induction-furnace equipment is now being used to heat parts prior to forging and swaging operations. By means of a special focus inductor coil, it is possible to concentrate the heat within a sharply defined zone. Either a uniform temperature throughout or a graded temperature in the heated zone can be obtained. As big a section as a 3-in. diam. billet can be uniformly heated to 2,200 deg. F. in 2 min. Method is said to lend itself well to automatic control. (53)

The consumption of finished steel in the United States increased from 1,060 lb. per family in 1900 to 2,350 lb. of steel per family in 1936. (54)

(*For details, write the editor, giving the item number.*)



Ambrose Swasey

1846-1937

THE DEATH of Ambrose Swasey, on June 15 at his summer home in Exeter, N. H., at the age of 90, marked the passing of the greatest of the remaining pioneers in American engineering and industry. All the honors that engineers can bestow had been heaped upon him. His great achievements in science, engineering and industry won him honors and admiration; his modesty, friendliness and great character won him a host of friends who will keenly feel his loss.

Like many others of his contemporaries, Ambrose Swasey started his career as an apprentice. In December 1846, at the age of 18 he started work as an apprentice in the Exeter Machine Works where he met Worcester R. Warner. The two became close friends and together went to the Pratt & Whitney Company in 1869. Eleven years later, 1880, Warner and Swasey started a small shop of their own—the beginning of the Warner & Swasey Company.

Among the engineering achievements of Ambrose Swasey are the design and building of telescopes, perfection of a milling machine for cutting epicyloidal teeth, a new process for generating and cutting spur gear teeth, the famous "dividing engine," the manufacture of gunsights, range finders, binoculars, astronomical instruments, and the development of the line of well-known turret lathes.

To engineers the world over, Ambrose Swasey is known as the man who was instrumental in the establishing of the Engineering Foundation to which he contributed $750,000 for its maintenance. He was one of the founders and a past president of the American Society of Mechanical Engineers, a trustee of the Case School of Applied Science, an officer of the French Legion of Honor, was awarded the John Fritz Gold Medal, the Franklin Gold Medal of the Franklin Institute, and the A.S.M.E. Medal. Last December, on the occasion of his 90th birthday he was presented the Hoover Gold Medal, the highest honor that can be bestowed on any engineer, awarded by the National Engineering Societies "to a fellow engineer for distinguished public service."

Ambrose Swasey will long be remembered; his biography will be an inspiration to many.

Just a Chat with the Editors

CLOSELY associated with and greatly affecting the work of the designing engineer is the patent attorney or patent department. In every new design or redesign there are always the questions, "Is it patentable? Is it an infringement?" In many cases the answer should be obvious, yet hours of precious time and effort are wasted in engineering departments because of ignorance of elementary facts about patent law.

It is not uncommon for an engineering department to spend a great deal of time and money to develop a new

mechanism or product, only to find out afterward that the new creation cannot be marketed because it is in conflict with some fundamental patent consideration. If on the other hand the engineering department must appeal to the patent attorney for a decision on every step in the development of a new product, the rate of producing new designs becomes extremly slow and the time of the patent attorney is taken up answering trivialities. Either the engineering department must wait for a decision from the patent attorney or the designer must go ahead and take a chance.

Apparently the only logical solution to this problem is for the designing engineer to obtain a general knowledge of basic patent law. Thereby he can save much time and push his development program with greater speed, precision and confidence. Fewer false starts will be made, time in both the engineering department and the patent department will be used to better advantage.

It is not to be inferred that the designer should have a detailed knowledge of patent law to enable him to get along without the advice or services of a patent attorney. Patent attorneys, like engineers, are specialists and rarely can one man be expected to be both. But the man who has a broad general knowledge of subjects that, though not directly in his specialty, have a bearing on his work, is able to accomplish much, with precision and dispatch.

To meet the needs of designers for authoritative information relating to patent law, we have induced H. A. Toulmin, Jr. to prepare a number of articles on the subject and to conduct a column, which beginning in this number, will appear every month, wherein he will present and explain outstanding court decisions on patent cases. He is well known as the author of "Invention and The Law," "Patent Law for the Inventor and the Executive" and other books, and is a member of the firm of Toulmin and Toulmin, the firm of patent attorneys who secured the basic patents on the airplane for the Wright brothers and successfully prosecuted their suits for infringement.

This increased service to readers of *Product Engineering* in no way affects the balanced coverage of design subjects and engineering data that has been maintained in the past. This has been made possible by increasing the number of editorial pages.

Similarly, the color illustrated articles on color, which will appear in alternate issues, and our own use of color to emphasize features of design as appearing in this number, are additional features of the increased editorial scope and reader service of *Product Engineering*.

Case Histories in Patent Law

H. A. TOULMIN, JR.

[EDITOR'S NOTE: *We wish to emphasize that in consenting to furnish this column wherein general explanations of the law in specific patent cases are set forth, Col. H. A. Toulmin, Jr. wants it clearly understood "that each actual case should be submitted to your own patent attorney who is the only one familiar enough to advise you accurately." The purpose of these explanations is to give a better general understanding of questions of patent law.*]

QUESTION: Is it true that if a design involves only the application of mechanical skill or engineering ability, it is not patentable even though it embodies great improvements over previous designs, in being lighter, simpler and cheaper?

ANSWER: The law is, briefly, that for patentable invention there must be involved more than the exercise of mere mechanical skill or engineering knowledge. It presupposes the exercise of the creative function—of inventive genius. If the improvements are such as might be expected of anyone familiar with the art and possessed of the mechanical skill or engineering knowledge usual in that art, it is not patentable invention.

As with any involved and complicated mental processes, it is exceedingly difficult to determine where ordinary skill or knowledge leaves off and invention begins.

Scientific knowledge and artisan skill are common property, not subject to patent protection. They can, of course, be used in an invention, but they must be accompanied by ingenious inventive accomplishment. Therefore the court will, after informing itself upon the prior state of the art, determine whether the "invention" could have been made by anyone having the mental equipment of the skilled mechanic or engineer in that industry.

TYPICAL CASES: That improvements are not patentable if they do not involve inventive genius was demonstrated in the case of *De Forest Radio Co.* v. *General Electric Co.*, when the court invalidated the Langmuir patent covering a high-vacuum discharge tube used as a detector and as an amplifier in radio communication and telephony. The Court said:

"That the high-vacuum tube was an improvement over the low-vacuum tube of great importance, is not open to doubt. Even though the improvement was accomplished by so simple a change in structure as could be brought about by reducing the pressure in the well-known low-vacuum tube by a few microns, still it may be invention. Whether it is or not depends upon a question of fact, whether the relationship of the degree of vacuum within the tube, to ionization, and hence to the stability and effectiveness of discharge passing from cathode to anode, was known to the art when Langmuir began his experiments. If that relationship was then known, it required no inventive genius to avoid ionization and secure the desired result by creating the vacuum in a DeForest tube or other form of low-vacuum discharge device."

The Court found that the process for creating a high vacuum was already well known and that it was also known that the bad effects of ionization could be eliminated by increasing the vacuum.

Another court decision on this question related to an improvement on a certain machine that displayed an objectionable tendency to reverse in operation. An engineer overcame that tendency by making the hand wheel heavier so that the increased inertia of the wheel would provide sufficient resistance to the force causing reversal. This, of course, was a well-known principle of mechanics and therefore was not something new brought into existence by the inventive faculty. The Court said:

"The substitution of the heavier wheel was not the product of a creative mental conception but merely the result of the exercise of the ordinary faculties of reasoning upon the materials supplied by a special knowledge, and the facility of manipulation which results from its habitual and intelligent practice."

However, if a new and valuable result—and especially if it be one long sought for—is achieved, the presumption is that the new design is patentable invention even though all of the elements are old and well-known.

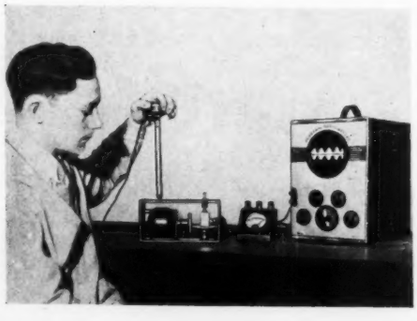
New Materials and Parts

Molded Rubber Wheel

Combines a hard rubber center with a soft rubber tread, replacing the former pressed metal wheel with a lathe-cut rubber tire cemented in place. A bronze oilless bearing is cast in each wheel to eliminate squeaks and necessity for oiling. Although designed especially for vacuum cleaners, this all-rubber wheel is adaptable to many other uses. The B. F. Goodrich Co., Akron, Ohio.

Crystal Vibration Pick-Up

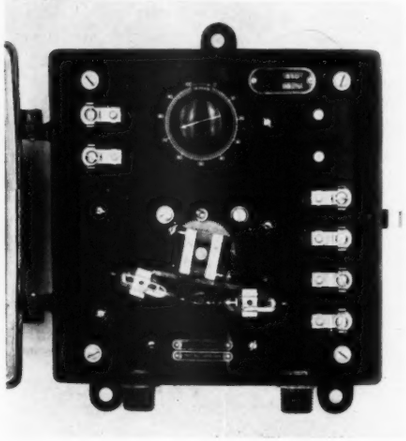
Intended for general application in field of vibration and noise-reduction analysis. Sensitive enough to detect vibrations from escapement of a wrist-watch yet sturdy enough to withstand vibrations up to 1/16 in. amplitude. Device is of inertia type and is designed so that crystal, mounted inside aluminum case, has no direct mechanical connection with the 8-in. duralumin prod provided. When the case, which weighs only 4 oz., vibrates, the crystal flexes of its own inertia and sets up voltage impulses



of a wave form corresponding to that of the vibration. Response is said to be practically linear up to resonant frequency of 2,500 cycles, and output sensitivity for 0.001 in. motion at 400 cycles per sec. is two volts (r.m.s.). In connection with an oscilloscope, it can be used to determine the frequency, amplitude, and velocity of the vibration. Sundt Engineering Co., 4238 Lincoln Ave., Chicago, Ill.

Three-Ply Thermostatic Metal

Addition of third element between active and inactive members of thermostatic metal results in smooth operation and uniform movement throughout entire range of from 0 to 1,200 deg. F. For general application in heat-control field. Available in strip form and also in any shape desired. Previously described in May issue but address of manufacturer erroneously stated. Laminated Metals Corp., 775 Eddy St., Providence, R. I.

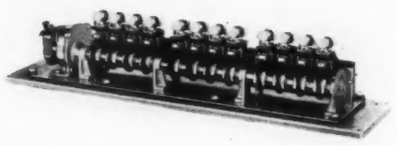


Anticipator for Pyrometer Controllers

A device known as the B-Linator for use with automatic pyrometer controllers such as used on industrial heating furnaces. The device enables the pyrometer controller to anticipate temperature changes and correct the fuel consumption sufficiently in advance to prevent the temperature from cycling, that is, repeatedly rising above and falling below the control point. Can be used with practically all commonly used types of pyrometer controllers and can be added to present installations as well as incorporated in the control circuit of new equipment. The Bristol Co., Waterbury, Conn.

Timing Dial

For mounting on the camshafts of Staley time cycle controllers, the camshaft of the controller actuating a rocker arm assembly on which are mounted metallic mercury switches marked in degrees from 0 to 360. By means of gear changes the speed of the camshaft

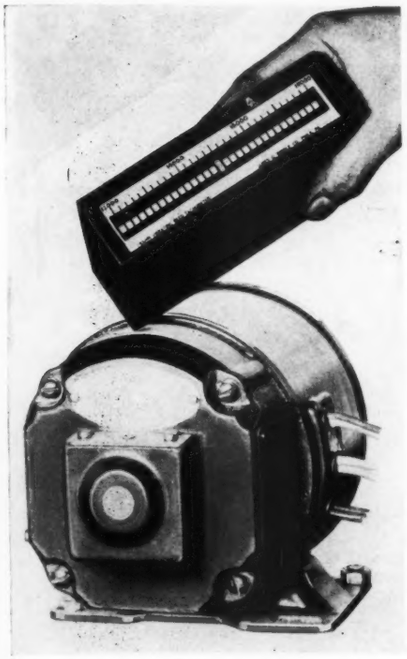


can be varied from 1 to 25 r.p.m., giving a wide range of timing. Speeds from 1 break in 1 min. to 60 breaks per min. are available on the 611 Model and speeds from 1 break in 15 min. to 25 breaks per min. are available on the 602 Model. A wide range of time settings for the control of automatic, sequence-timed operations can be obtained. Electric Switch Corp., Columbus, Ind.

Acid Resisting Alloy

A further addition to the series of Hastelloy alloys, known as "Hastelloy B," is now being offered for use under extremely severe conditions of corrosion. Produced primarily for service in equipment handling hydrochloric acid in all concentrations and at temperatures up to and including the boiling point. Also resists action of sulphuric and phosphoric acids, acetic and other organic acids, and in non-oxidizing acid chloride solutions. A 20 per cent hydrochloric acid solution at the boiling point penetrates the metal at only 0.0016 in. per month. The alloy is composed of nickel, molybdenum and iron. It contains less iron and molybdenum than Hastelloy A and thereby possesses a higher ultimate tensile strength and higher yield point with practically no loss in ductility or in reduction of area. The tensile strength in the forged, rolled and fully annealed state is

135,000 to 140,000 lb. per sq. in. Hastelloy B is available as castings, wrought parts, rolled plate and sheet, wire and welded tubing. Haynes Stellite Co., 205 East 42d St., New York, N. Y.

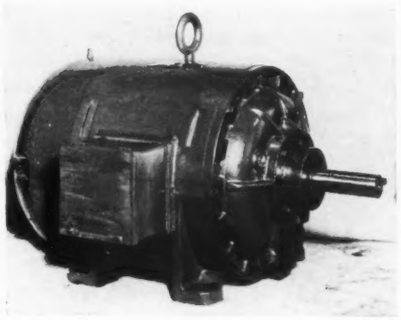


Vibrating-Reed Tachometer

For speeds up to 30,000 r.p.m. or for measuring frequency of vibrations of pneumatic hammers, drills and other vibrating equipment. Operates on the vibrating reed principle, it being merely necessary to hold or mount the instrument on the machine. Available in three types of mountings, the rectangular and round type for permanent mounting and the hand type for portable use, and with either one or two rows of reeds. Available for measuring speeds or vibrations from 9,000 to 30,000 r.p.m. any one instrument covering a range of 3,000 or 6,000 r.p.m. James G. Biddle Co., 1211-13 Arch St., Philadelphia, Pa.

Fan-Cooled Motor

A new design of dual ventilated fan-cooled Type CS squirrel-cage motor designed for protection against abrasive dust, moisture and corrosion. Can be installed outdoors without additional protection. Motor frame contains two separate sets of air ducts separated by a common wall. The internal ducts are open in the interior part of the motor and the external ducts are open on the outside of the motor frame. An internal fan on the rotor circulates warm air through the internal ducts, the walls of which are cooled by large volumes of cool air blown through the external



ducts by an external fan. The cartridge type bearings are grease lubricated. Fresh grease enters the outside edge at the top of the bearing and excess or used grease is discharged at the bottom inner edge to the overflow sump where it can readily be removed through a pipe plug opening. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Heat Resisting Lacquer

A new line of clear, pigmented, air drying lacquers, specially designed for finishing electrical equipment and other products normally subjected to elevated temperatures. Known as Durheat lacquers, they retain their flexibility, color and adhesion indefinitely at temperatures up to 300 deg. F. Available in clear, black, white and all colors and can be applied by either dipping or spraying. Can be applied directly to any metal except polished chromium for which application the surface to be finished must first be covered with a baked coat of chroprime. Other applications are direct and indirect lighting fixtures, lamp inclosures, radiant heaters, electric signs, electric ranges, and similar equipment. Maas & Waldstein Co., Newark, N. J.

Pump and Valve Unit

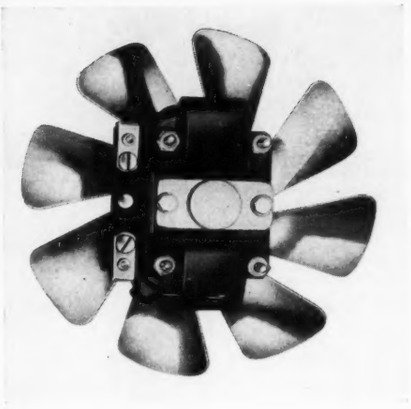
Designed especially for actuating arbor presses, clamping fixtures and similar devices. Embodies in a single housing two pumps and all of the control valves except the remote pilot valve. Known as the WX Model. Quick action for the approach and return of a ram or clamping member is taken care of by a large capacity pump with a small sized pump producing the clamping or working pressure. Of compact design, this arrangement reduces piping to a minimum and also results in low power consumption and less heating of the oil as only the small pump is operated at the high working pressures. Both pumps are mounted on the same shaft and driven at motor speed, 1,200 r.p.m. The units are built in several sizes and can be supplied with either foot or flange mountings. An oil reservoir with motor base for attaching a foot mounted unit can also be furnished together with any type of remote pilot valve that may be desired. Sundstrand Machine Tool Co., Rockford, Ill.

Treadle-Operated Water-Tight Pushbutton Station

For use in damp or wet locations. Case and cover are made of cast iron and a cast-iron foot pedal or treadle is built into the cover. The pedal operates a standard General Electric heavy-duty type pushbutton unit mounted inside the case. Stops limit the travel of the treadle in either direction so that the electrical parts cannot be damaged by excessive pressure on the treadle. Pedal automatically returns to its neutral position. The station is available either with a single-action or a double-action treadle. General Electric Co., Schenectady, N. Y.

Small Motor-Fan Unit

A new small motor of exceptionally high starting torque furnished with or without fan and quiet running. Die-cast bearing brackets carry large oilless bearings so that the motor requires no lubrication attention. Motor is symmetrical and has four studs for mounting. This 2-pole motor draws 15 watts and is available for either line or low voltage, 60 cycle, a.c. use. Illustration shows the motor driving a 5⅜ in. noiseless pressure fan of high static pressure



efficiency. The delivery is 75 c.f.m. at 0.04 in. in hydrostatic pressure. The Russell Electric Co., 334 W. Huron St., Chicago, Ill.

Crystal-Clear Resin

Is water-white hydrocarbon resin in crystal form. Possesses properties such as color, stability and resistance to after-yellowing, neutrality, permanent thermoplasticity, and transparency. Is readily soluble in most commercially used solvents with exception of alcohols and water. Known as Nevillite, it is a brittle solid at room temperatures and is tasteless and odorless. Recommended for use in white and pastel finishes and in clear plastic moldings to extend the molding resin. The Neville Co., Pittsburgh, Pa.

Combination Temperature Control

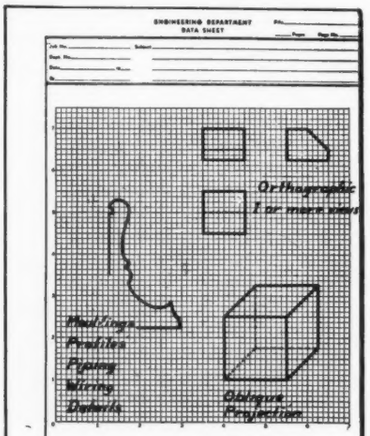
A twin automatic thermostatic control inclosed in one case, designed to open the circuit to prevent excessively high temperatures or excessively low temperatures. Especially developed to control the circulating fan in warm air furnaces to prevent excessive temperatures in the heating ducts or furnace and to prevent blowing of cold air into the room until the furnace has come up to temperature. Setting can be quickly altered. Construction consists of a typical Mercoid switch which is tilted by the action of a bi-metal helix. The Mercoid Corp., 4201 Belmont Ave., Chicago, Ill.

Automotive Finish

To be known as "Automotive Pyralux." Designed chiefly for touching-up synthetic resin finishes and for recoloring used cars, it combines the quick-drying qualities of lacquers and the luster of synthetic resin enamels, requiring no rubbing. Its chalking resistance is comparable to that of baking enamel. The new finish is offered in black and 26 shades. E. I. DuPont de Nemours & Co., Inc., Wilmington, Del.

Sketch Sheets

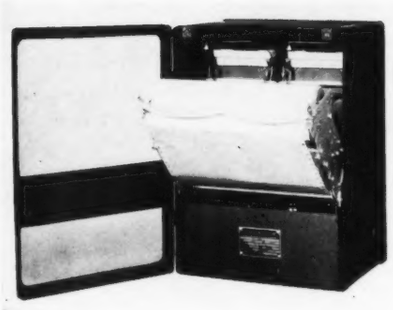
Sheets, 8½x11 in., with a 7x7½ in. drawing area laid out in ⅛ in. squares with the inch lines heavy and numbered. Identification lines are provided. Are useful for all types of sketches, records, operations and estimates. Also available with a 7x10 in. sketching area without



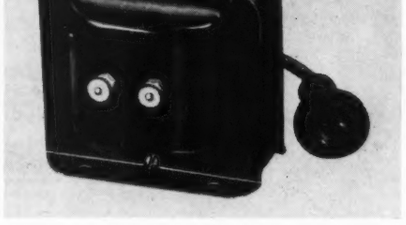
other printing. Blueprints can be made from either black ink or pencil drawings. Being made of rag tracing paper, the sheets will not deteriorate and can be used for permanent records. Available in packages of 40 and 100 sheets. Wade Instrument Co., 2246 Brooklyn Station, Cleveland, Ohio.

Double Photoelectric Recorder

For recording simultaneously on one chart, two electrical quantities as low as one microampere, full scale, and requiring a power consumption of only 0.000000001 watt from the measured circuit. Can be used wherever simultaneous readings are desired. By means of an



optic and photoelectric system, and power circuit, the measuring element causes the recording element to follow its movement. There is no power consumption from measured circuit other than that required for measuring element. General Electric Co., Schenectady, N. Y.



Voltage Compensator

Transformer that serves as a voltage compensator to supply regulated power to devices requiring a constant voltage. Variations in line voltage are instantaneously corrected and a constant low voltage level maintained. This transformer is built to individual specifications and is specially suited to low voltage applications such as photoelectric cells, X-ray lamp filaments, exciter lamps and all kinds of precision and recording instruments. Sola Electric Co., 2525 Clybourn Ave., Chicago, Ill.

Free-Machining Case Hardening Steel

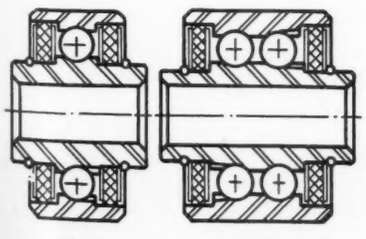
A 0.40 to 0.50 carbon, open-hearth steel available under the trade name Speed Treat X-1545. It is claimed that this steel approaches SAE 1112 Bessemer in free machining and can be machined much faster than SAE 1045. It is also claimed to be from 5,000 to 10,000 lb. per sq. in. stronger in tensile strength than SAE 1045. Said to have excellent case hardening properties, giving a tough, ductile core of approximately 28 Rockwell C in combination with a hard uniform surface of from 63 to 66 Rockwell C. Physical properties can be developed by heat-treatment. Monarch Steel Co., Indianapolis, Ind.

Table Drawing Stand

A portable drawing stand, easily attached to any size or shape table. To apply two rods each bent at one end are inserted in the formed metal base, the bent ends at the sides of the table. The rods are sprung down at the ends and end clips are slid up under the table, the clips binding on the rods to keep the rod tension on the base and to secure the base to the table. Sponge rubber at all contacting points protects the table. The drawing stand is adjustable to any position. Height and angle are obtained by the use of two arms and brackets held by bolts and wing nuts. Westbrook Equipment Co., 10016 Greenview Ave., Garfield Heights, Cleveland, Ohio.

Double Felt-Seal Bearings

New sizes and several entirely new types added to the series of bearings designed primarily for the aviation field but currently used by other industries as well. The new bearings are of the double felt-seal type and are known as the KF, KF-A, and DF series. Both the KF and KF-A are designed with a single row of balls while the DF makes use of a double row of balls. These bearings, of which the K-A single row radial with double metal shields is an Army Air Corps Standard, and the KF a Navy Standard, round out a line which is said to conform to specifications of aircraft engineers for weight, tolerances, dimensions and proper radial and thrust capacity. All series and sizes shown in the Fafnir 1937 Aircraft Catalog are in production and will be carried as stock items. The Fafnir Bearing Co., New Britain, Conn.



KF DF

Manufacturers' Publications

BALL BEARINGS—New Departure Mfg. Co., Bristol, Conn. Handbook, 146 pages, 6 x 8½ in., spiral binding. Vol. I of the new eleventh edition of the New Departure handbook containing dimensional, load rating and mounting data pertinent to their standard types of ball bearings.

CHAINS—Baldwin-Duckworth Chain Corp., Springfield, Mass. Bulletin 59, 8 pages, 8¼ x 10¾ in. Covering non-corrosive and heat-resistant chains. Includes tables of resistance to corroding agents of stainless steel chain and bronze chain together with standard attachments for bronze and stainless steel roller chains.

ELECTRIC HEATING UNITS AND DEVICES—General Electric Co., Schenectady, N.Y. Bulletin GED-650, 60 pages, 8½x11 in. Data on a wide variety of small electric heating units and devices.

ENGINEERING PROPERTIES OF "K" MONEL.—The International Nickel Co., 67 Wall St., New York, N. Y. Bulletin No. T9, 16 pages, 8½ x 11 in. Containing charts and tables giving the properties and heat-treatment of a copper-nickel-aluminum alloy known as "K" Monel. Typical application data and information on machine properties are included.

FLEXIBLE COUPLINGS — John Waldron Corp., New Brunswick, N. J. Bulletin No. 53, 4 pages, 8¼ x 10¾ in. Descriptive data on the new Francke fractional horsepower all-steel flexible coupling.

FLEXIBLE TUBING—The American Brass Co., American Metal Hose Branch, Waterbury, Conn. Bulletin SS-3, 16 pages, 8½ x 11 in. Descriptive data, applications, and typical installations of seamless flexible metal tubing, including numerous application pictures.

GEARS AND REDUCERS—The Ohio Gear Co., 1333 East 179th St., Cleveland, Ohio. Second Edition, Catalog No. 36, 136 pages, 4½ x 7¼ in., spiral binding. Covering their line of gears, speed reducers, chain drives, couplings, pulleys, etc. Twenty-five tables of technical data given in the appendix include chain capacities, gear formulas, gear tables, S.A.E. steel specifications, and similar data.

HARD FACING—Haynes Stellite Co., Kokomo, Ind. Booklet, 51 pages, 8½ x 11 in. In addition to considerable space devoted to Haynes Stellite J-metal cutting tools, a section is devoted to a concise summary of hard-facing applications in the machine shop. An appendix contains complete hardness conversion charts and S.A.E. steel specifications.

LIGNUM-VITAE FACT FLASHES—Lignum-Vitae Products Corp., Jersey City, N. J. Leaflet, 8½ x 11 in. A new bulletin to be issued periodically, describing the natural self-lubricating and acid-resisting properties of the hard, heavy wood known as lignum-vitae, and reporting in brief and convenient form technical news and data on its application to mechanical uses.

MAGNETIC SEPARATOR—Stearns Magnetic Mfg. Co., Milwaukee, Wis. Bulletin "DH' 4 pages, 8½x11 in. Describing a recently developed drum-type magnetic separator for purifying dry pulverized material, applying particularly to operations where the elimination of iron or iron bearing minerals is essential.

METALGRAM—Apex Smelting Co., 2554 Fillmore St., Chicago, Ill. Data Sheet No. 20, 4 pages, 8½x11 in. Covers the impact strength of zinc base die-cast alloy No. 6 when cast under the different metal, die and pressure variables.

METAL SPRAYING—Metallizing Company of America, Inc., 1351 E. 17th St., Los Angeles, Calif. Booklet, 36 pages, 9x12 in. The story of the metal spraying process and its applications is pictorially presented in this interesting booklet.

MINIATURE PANEL INSTRUMENTS—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Catalog Section 43-350, 15 pages, 8½x11 in. Describes miniature panel instruments for industrial and radio applications. Includes dimensional drawings, wiring diagrams and ratings.

MOTOR CARTRIDGE UNIT—The Fafnir Bearing Co., New Britain, Conn. Folder, 8½x11 in. Presents the advantages of ball bearing-equipped motors over plain bearing motors and describes the application of ball bearing motor cartridges for converting plain bearing motors into the ball bearing type.

MOTOR-MOUNTED PUMPS—DeLaval Steam Turbine Co., Trenton, N. J. Catalog BF-100, 1-2 pages, 9½ x 11 in. Describes pump and its applications. Dimension tables, rating tables and pipe friction tables are included.

MOTORS—General Electric Co., Schenectady, N. Y. Leaflet, GEA-2492, 8 x 10½ in. Illustrations and brief descriptions of numerous fractional-horsepower motors for a wide variety of applications.

OPERATING VALVES—Ross Operating Valve Co., 488 Epworth Blvd., Detroit, Mich. Catalog No. 36, 9 x 11½ in., 24 pages. Describes construction, design, types and applications of valves for controlling single and double acting cylinders for hand, foot and electrical operation.

PILLOW BLOCKS—Randall Graphite Products Corp., 609-613 West Lake St., Chicago, Ill. Catalog, 24 pages, 5½ x 8½ in. Specifications, descriptions and installation data on six types of pillow blocks. Also describes oil cups, safety collars, washers and rubber mountings.

"PLASTACELE" MOLDING POWDER — E. I. duPont de Nemours & Co., Inc., Arlington, N. J. Booklet, 24 pages, 6¾ x 9¾ in. Data on "Plastacele" cellulose acetate molding powder, compression and injection molding methods, types and forms, properties and uses.

POTENTIOMETER—The Bristol Co., Waterbury, Conn. Bulletin 482, 8 pages, 8x10½ in. Presenting a new direct-reading, round-chart recording potentiometer, known as the Pyromaster. Includes engineering data pertaining to the Pyromaster in the following forms: pyrometer, tachometer, resistance thermometer, millivoltmeter and milliammeter.

PYROMETERS—The Brown Instrument Co., Philadelphia, Pa. Catalog No. 15-C, 40 pages, 7¾x10½ in. Covering complete line of millivoltmeter pyrometers. Also describes moisture-proof and multiple key switches, control relays, valve mechanisms, thermocouples and accessories, and the new Brown Optimatic—a self-balancing optical pyrometer, the Analy-Graph—for recording furnace atmospheres, and the Protectoglo—a combustion safeguard.

RADIO CABINET DESIGN—Beetle Products Div., American Cyanamid Co., 39 Rockefeller Plaza, New York, N.Y. Booklet, 8 pages, 9x12 in. Advantages of using Beetle in radio cabinet design for improved appearance and to simplify production are discussed.

ROLLER CHAINS—Diamond Chain & Mfg. Co., Indianapolis, Ind. Catalog No. 607, 96 pages, Data book containing complete information and prices on standard roller chains ranging from ⅜ in. to 2 in. pitch together with data and list prices on stock and made-to-order sprockets.

SCREW PRODUCTS—The Bristol Co., Waterbury, Conn. Bulletin 833, 3½ x 6¼ in. Complete data on Bristol socket setscrews and socket head capscrews as approved by The American Standards Association.

SPRAY NOZZLES — Yarnall-Waring Co., Chestnut Hill, Philadelphia, Pa. Bulletin N-615, 4 pages, 8 x 11½ in. Contains data on the smaller sizes of Yarway involute spray nozzles for air conditioning and for general industrial uses.

SPRINGS—The Beryllium Corporation of Pennsylvania, Reading, Pa. Bulletin "D" 13 pages, 8¾ x 11¼ in. Engineering data on "How to Design Flat Springs to Meet Definite Requirements."

SUSPENDED MAGNETS—Stearns Magnetic Mfg. Co., Milwaukee, Wis. Bulletin, 4 pages, 8½x11 in. Describing various types of safety suspended circular, rectangular and hand magnets.

VOLTAGE REGULATORS — Ward Leonard Electric Co., Mt. Vernon, N. Y. Bulletins 5601 and 5602, 8 pages each, 8 x 10½ in. Data on Type EF and Type EB electronic automatic alternator voltage regulators.

"WALWORTH TODAY"—Walworth Co., 60 East 42d St., New York, N. Y. Vol. I, No. 1, 12 pages, 8½ x 11 in. A new booklet to be published bi-monthly presenting their line of valves, fittings, pipe and tools and the variety of uses of these units. Featured in this issue is an article "Creep Testing of Metals" which is presented as the first of a series on laboratory technique as practiced by the company.

WIRING GUIDE—Anaconda Wire & Cable Co., 25 Broadway, New York, N.Y. Booklet No. C-35, 32 pages, 8½x11 in. "Industrial Guide for the Selection of Wire and Cable" discusses applications and factors affecting the selection of wire and cable. Colored layouts illustrate typical power supply circuits and tables covering practical limitations to be considered are included.

Books and Bulletins

S.A.E. Handbook

1937 EDITION. *475 pages, 6x8½ in. Blue clothboard covers. Published annually by the Society of Automotive Engineers, Inc., 29 West 39th St., New York, N. Y. Price $5.00 to non-members.*

This yearly handbook contains a list of S.A.E. standards and recommended practices and also the Army-Navy standards for aircraft and S.A.E. aircraft specifications. Included in the 1937 edition are 9 new specifications and 27 revised specifications approved and adopted by the Society in June 1936 and January 1937. Three specifications have been corrected and 7 cancelled.

The handbook is divided into 10 sections including units, parts and fittings; processed materials; fabricated materials; screws, bolts and washers; tests, ratings and codes; transportation and maintenance; tools and production equipment; nomenclature and definitions; miscellaneous tables; and a section devoted to standard committee regulations and a partial list of American standards.

Motor and Control Applications

GEORGE H. HALL. *259 pages, 6x9 in. 167 illustrations and diagrams, 15 tables. Clothboard covers. Published by McGraw-Hill Book Co., Inc., 330 West 42d St., New York, N. Y. Price $3.00.*

Descriptions and application data on the various types of motors and controls are presented in a manner intended to assist the designer of machines and machinery in applying such electric equipment. An introductory chapter is devoted to the determination of machine requirements, following which motors and controls are discussed first separately and then jointly in chapters dealing with typical classes of applications. The book, therefore, is so arranged as to present in concise form the characteristics that are obtainable from the various types of motors and the performances that may be secured from them by the selection of suitable control, thereby linking the motors and control as produced by the electrical manufacturers to the equipment on which it is applied by the machine designer or plant engineer. A concluding chapter presents data and dimensions of motors as standardized by the National Electrical Manufacturers Association.

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Temperature Tables

NATIONAL BUREAU OF STANDARDS, U. S. DEPARTMENT OF COMMERCE, *Washington, D. C. Folder* 8x10¼ *in. Price* 5 *cents.*

Consists of two conversion tables for converting degrees Centigrade to degrees Fahrenheit and from degrees Fahrenheit to degrees Centigrade and a table of melting points of the chemical elements.

Effects of Service on Automobile Crankcase Oils

JAMES I. CLOWER AND N. W. CONNER. *40 pages, 6x9 in. Engineering Experiment Station Series Bulletin No. 28. Published by the Virginia Polytechnic Institute, Blacksburg, Pa. Price 25 cents.*

The rate of wear of an automobile motor is largely dependent on the maintenance of oil in such a condition as to render satisfactory lubrication. This investigation presents the results of laboratory tests on oil samples from a Chevrolet and a Pontiac automobile to show the changes which occur in oil efficiency and oil properties after various mileages of service. Resultant changes in viscosity, dilution, film breakdown, wear results, specific gravity, etc., are discussed.

An Anaylsis of An Installation of Dust Suppression Equipment

HUGH E. KEELER. *8 pages, 8½x11 in. Department of Engineering Research, University of Michigan, Project No.* 1M72 *for the Claude B. Schneible Co.,* 3951 *Lawrence Ave., Chicago, Ill.*

A report on the dust-removal efficiency of the Schneible multi-wash dust collector, presented as the result of a series of tests. The report contains descriptions and illustrations of the testing equipment and apparatus used in obtaining dust samples and conducting the tests, presenting the methods of procedure and tabulated results of the tests.

PRODUCT ENGINEERING ✦ REFERENCE BOOK SHEET

Formulas for Circular Rings

Table of Equations for Calculating Stresses and Deflections

RAYMOND J. ROARK
Professor of Mechanics, University of Wisconsin

IN LARGE pipe-lines, tanks, aircraft and submarines, the circular ring is an important structural element, and for correct design it is often necessary to calculate the stresses and deflections produced in such a ring under various conditions of loading and support.

The closed ring is statically indeterminate and, though on account of the symmetry of its form analysis is not difficult, the necessary calculations are sometimes very laborious. For this reason formulas for the more common cases of loading are convenient, especially since by superposition a limited number of such formulas can be combined so as to cover almost any condition of loading and support likely to occur.

Several tables of such formulas have been published. Some are of special interest to aeronautical engineers who must design rings to serve as bulkheads in thin metal fuselages, others being intended for use by the structural engineer in designing pipe-lines, tanks, etc. Among these are: "Formulas for the Stress Analysis of Circular Rings in a Monocoque Fuselage," Technical Note No. 462 of the National Advisory Committee for Aeronautics, by R. A. Miller and K. D. Wood; and "Stress Coefficients for Large Horizontal Pipes," J. M. Paris, *Engineering News-Record*, Vol. 87, No. 19, Nov. 1921.

The table beginning on the next page is believed to be more extensive than those formerly available, especially with respect to formulas for deflection and for the bending moments in pipes containing water and in the rings that support such pipes. Many of the formulas in it, however, were taken from the two articles mentioned above, the notation being slightly modified for the sake of consistency.

The table gives equations for the bending moment M, tangential tension T and radial shear V at any section of the ring, and for the horizontal and vertical deflections, D_x and D_y respectively. Referring to Fig. 1, note that M_1, T_1, V_1, M, T, and V are positive when as shown; negative when reversed. All applied forces and couples are likewise positive when as shown; negative when reversed. The following notation is employed: E = modulus of elasticity (lb. per sq. in.); I = moment of inertia of radial cross-section of ring (in.^{4}); W or F, as shown = applied load or reaction (lb.); w = applied load (lb. per linear in. measured around circumference); K = weight of contained liquid (lb. per cu. in.); Z = sin X; U = cos X; S = sin θ; C = cos θ; N = sin ϕ; H = cos ϕ; P = sin β; and Q = cos β. Also note that all angles are in radians, distances in in., forces in lb., moments in in.-lb., and that $+D_x$ or $+D_y$ means increase and $-D_x$ or $-D_y$ means decrease in diameter.

The formulas presented here have been derived by the methods of least work,

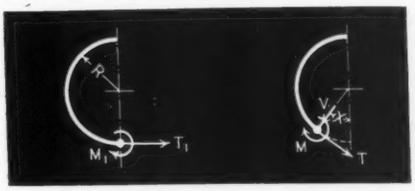


Fig. 1—Bending moment, tangential tension, and radial shear are positive in sign when directed as shown here; negative when reversed.

strain energy, and slope-deflection, and are based on the following assumptions:

1. The ring is of uniform cross-section, with respect to any radial plane.

2. The ring is of such large radius in comparison with its radial thickness that the ordinary flexure formulas for straight beams are applicable.

3. It is not, at any point, stressed beyond the elastic limit.

4. It is not so severely deformed as to lose its essentially circular shape.

5. For pipes acting as beams between widely spaced supports, the distribution of shear stress across the section of the pipe is in accordance with the common theory of flexure.

There may be some question as to validity of the last of these assumptions, since tests have shown that when very thin tubes are subjected to bending the fiber stresses are not always proportional to the distance from the neutral axis and, when this is the case, the distribution of shear stress cannot conform to the common theory.

However, the tests referred to (see "The Need for Empirical Data for the Design of Aircraft Structures," Joseph S. Newall, *Journal of the Aeronautical Sciences*, March, 1937) were made on longitudinally reinforced cylinders so thin as to fail locally by elastic buckling and it is improbable that the results secured are indicative of the behavior of cylinders too thick to fail in this manner.

Moreover, it has been shown by another method of analysis and by tests (see "Design of Large Pipe Lines," Herman Schorer, *Transactions* of the American Society of Civil Engineers, Vol. 98, 1933, tests by the present author and others being described in the discussion of this paper) that the circumferential moments vanish in a pipe supported at intervals by rigid rings and filled with liquid, and supporting rings for large pipe lines have been successfully designed by formulas in agreement with those which will be presented later under Cases 23 and 24.

It will be noted that most of the formulas consist of the algebraic sum of a number of terms, each of which may be large in comparison with the end result. For this reason, accurate results will be obtained only when the calculations are made with great care and all terms should be carried to at least four significant figures.

Additional portions of the table will be presented in the next and following issues of *Product Engineering*. In addition, the use of the formulas and the way in which they may be combined by superposition will be illustrated. In this connection, two illustrative examples will be published, but not until after the cases which are involved in them have been given in the table.

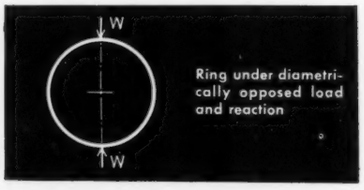
Formulas for Circular Rings

LOADING AND SUPPORT

Bending moment M, circumferential tension T, radial shear V at angular distance X from bottom of ring and for D_x change in horizontal diam., and D_y, change in vertical diam.

E = modulus of elasticity (lb. per sq.in.); I = moment of inertia of ring-wall cross-section (in.^{4}); W or F, as shown = applied load or reaction (lb.), w = applied load (lb. per linear in. measured around circumference); K = weight of contained liquid lb. per cu.in.; $Z = \sin X$; $U = \cos X$; $S = \sin \theta$; $C = \cos \theta$; $N = \sin \phi$; $H = \cos \phi$; $P = \sin \beta$; $Q = \cos \beta$.

1



Ring under diametrically opposed load and reaction

$$M = WR\,(0.3183 - \tfrac{1}{2}Z)$$

$$T = -\tfrac{1}{2}WZ$$

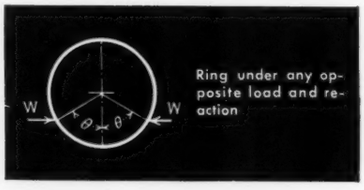
$$V = -\tfrac{1}{2}WU$$

$D_x = +\,0.137\,WR^3/EI$; $D_y = -\,0.149\,WR^3/EI$

Max. $+M = 0.3183\,WR$ at $X = 0$

Max. $-M = -\,0.1817\,WR$ at $X = \pi/2$

2



Ring under any opposite load and reaction

$(X=0$ to $X=\theta)$, $M=WR\,[0.3183\,(S-C\theta+U\theta-USC)-U+C]$
$(X=0$ to $X=\theta)$, $T=W\,[0.3183\,U\,(\theta-SC)-U]$
$(X=0$ to $X=\theta)$, $V=W\,[0.3183\,Z\,(SC-\theta)+Z]$
$(X=\theta$ to $X=\pi)$, $M=WR\,[0.3183\,(S-C\,\theta+U\,\theta-USC)]$
$(X=\theta$ to $X=\pi)$, $T=W\,[0.3183\,U\,(\theta-SC)]$
$(X=\theta$ to $X=\pi)$, $V=W\,[0.3183\,Z\,(SC-\theta)]$

$$D_x = \frac{WR^3}{EI}\,[0.6366\,(S-C\,\theta)+\tfrac{1}{2}\,(SC-\theta)]$$

$$D_y = \frac{WR^3}{EI}\left[\,0.6366\,(S-C\,\theta)+C+\tfrac{1}{2}\,S^2-1\,\right]$$

3

Ring under two diametrically opposed, equal and opposite localized couples M_0

$(X=0$ to $X=\pi/2)$, $M = M_0\,(0.6366\,U-\tfrac{1}{2})$

$(X=\pi/2$ to $X=\pi)$, $M = M_0\,(0.6366\,U+\tfrac{1}{2})$

$(X=0$ to $X=\pi)$. $T = \dfrac{M_0}{R}\,(0.6366\,U)$

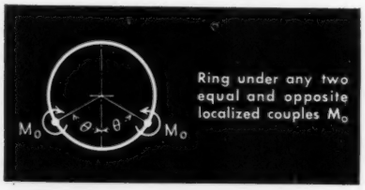
$(X=0$ to $X=\pi)$, $V = -\dfrac{M_0}{R}\,(0.6366\,Z)$

Max. $+M = +\tfrac{1}{2}\,M_0$ just above M_0

Max. $-M = -\tfrac{1}{2}\,M_0$ just below M_0

$D_x = 0$; $D_y = 0$

4



Ring under any two equal and opposite localized couples M_0

$(X=0$ to $X=\theta)$, $M = M_0\,[0.3183\,(2\,US+\theta)-1]$

$(X=0$ to $X=\theta)$, $T = \dfrac{M_0}{R}\,(0.6366\,US)$

$(X=0$ to $X=\theta)$, $V = -\dfrac{M_0}{R}\,(0.6366\,ZS)$

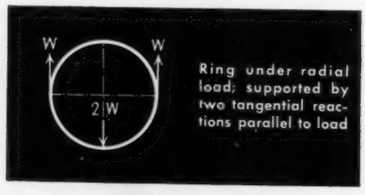
$(X=\theta$ to $X=\pi)$, $T = \dfrac{M_0}{R}\,(0.6366\,US)$; $(X=\theta$ to $X=\pi)$, $V = -\dfrac{M_0}{R}\,(0.6366\,ZS)$

$(X=\theta$ to $X=\pi)$, $M = M_0\,[0.3183\,(2\,US+\theta)]$

$$D_x = \frac{M_0R^2}{EI}\,(0.6366\,\theta-S)$$

$$D_y = \frac{M_0R^2}{EI}\,(0.6366\,\theta+C-1)$$

5

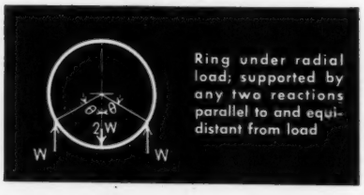


Ring under radial load; supported by two tangential reactions parallel to load

$(X=0$ to $X=\pi/2)$, $M = WR\,(0.3183\,U+Z-0.8183)$
$(X=0$ to $X=\pi/2)$, $T = W\,(0.3183\,U+Z)$
$(X=0$ to $X=\pi/2)$, $V = W\,(U-0.3183\,Z)$
$(X=\pi/2$ to $X=\pi)$, $M = WR\,(0.1817+0.3183\,U)$
$(X=\pi/2$ to $X=\pi)$, $T = W\,(0.3183\,U)$
$(X=\pi/2$ to $X=\pi)$, $V = -\,W\,(0.3183\,Z)$

$$D_x = \frac{WR^3}{EI}\,(-0.1366) \quad ; \quad D_y = \frac{WR^3}{EI}\,(0.1488)$$

6



Ring under radial load; supported by any two reactions parallel to and equidistant from load

$(X=0$ to $X=\theta)$, $M=WR\,[0.3183\,(S\,\theta+C+US^2-1)-S+Z]$
$(X=0$ to $X=\theta)$, $T=W\,(0.3183\,US^2+Z)$; $(X=0$ to $X=\theta)$, $V=W\,(U-0.3183\,ZS^2)$
$(X=\theta$ to $X=\pi)$, $M=WR\,[0.3183\,(S\theta+C+US^2-1)]$
$(X=\theta$ to $X=\pi)$, $T=W\,(0.3183\,US^2)$
$(X=\theta$ to $X=\pi)$, $V=-W\,(0.3183\,ZS^2)$

$$D_x = \frac{WR^3}{EI}\left[\tfrac{1}{2}\,(S^2+2)+0.6366\,(S\,\theta+C-1)-2\,S\right]$$

$$D_y = \frac{WR^3}{EI}\left[\tfrac{1}{2}\,(SC+\theta)+0.6366\,(S\,\theta+C-1)-S\right]$$

(Continued in August issue)